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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 :
H04M 11/06, H04L 12/64

A3

(11) International Publication Number: WO 97/37458

(43) International Publication Date: 9 October 1997 (09.10.97)

(21) International Application Number: PCT/US97/05173

(22) International Filing Date: 28 March 1997 (28.03.97)

(30) Priority Data:

08/625,769	29 March 1996 (29.03.96)	US
08/781,441	10 January 1997 (10.01.97)	US
08/781,444	10 January 1997 (10.01.97)	US
08/781,450	10 January 1997 (10.01.97)	US
08/781,482	10 January 1997 (10.01.97)	US

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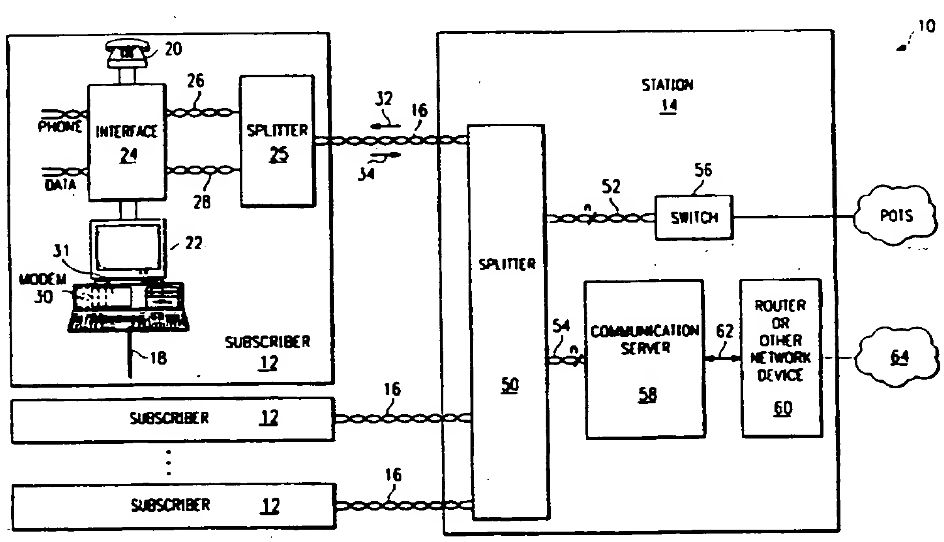
(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published

With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(88) Date of publication of the international search report: 13 November 1997 (13.11.97)

(54) Title: COMMUNICATION SERVER APPARATUS AND METHOD



(57) Abstract

A communication system (10) includes a number of subscribers (12) coupled to a station (14) using twisted pair subscriber line (16). In one embodiment, the station (14) includes a telephone switch (56) that provides telephone service to the subscriber (12), and a communication server (58) having a number of XDSL modems (160) that provide data service to the subscriber (12). The communication server (58) allows over subscription of data service to subscribers (12).

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INTERNATIONAL SEARCH REPORT

Intern. ial Application No
PCT/US 97/05173

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04M11/06 H04L12/64

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04M H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 247 347 A (LITTERAL LARRY A ET AL) 21 September 1993 see column 7, line 46 - column 8, line 49; figures 1,2 see column 11, line 1-19 ---	1,8,17, 33,43, 55,64, 99,105, 108,112, 114,117

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"P" document published prior to the international filing date but later than the priority date claimed

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

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Date of the actual completion of the international search	Date of mailing of the international search report
19 September 1997	01.10.97

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Dupuis, H

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 97/05173

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	FERNMELDE-INGENIEUR, vol. 48, no. 9, September 1994, GERMANY, pages 1-28, XP000619688 HESSENMULLER ET AL: "Access Network Structures for Interactive Video Services. 2" see paragraph 4.1 - paragraph 4.2 see paragraph 4.4; figure 16 see paragraph 4.6 ---	1,8,17, 33,43, 55,64, 99,105, 108,112, 114,117
A	FERNMELDE INGENIEUR, DER, vol. 48, no. 8, August 1994, pages 1-32, XP000647017 HESSENMUELLER H ET AL: "ZUGANGSNETZSTRUKTUREN FUER INTERAKTIVE VIDEODIENSTE (TEIL 1)" see paragraph 0 -----	1,8,17, 33,43, 55,64, 75,84, 99,105, 108,112, 114,117

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Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 97/05173

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5247347 A	21-09-93	AU 660710 B	06-07-95
		AU 2489492 A	27-04-93
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		EP 0605454 A	13-07-94
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		US 5528281 A	18-06-96
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A2

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Published

Without international search report and to be republished upon receipt of that report.

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YU	Yugoslavia
ZW	Zimbabwe

BNSDOCID: <WO___9737458A2_I_>

COMMUNICATION SERVER APPARATUS AND METHOD

TECHNICAL FIELD OF THE INVENTION

This invention relates in general to data communication, and more particularly to a communication server apparatus and method.

BACKGROUND OF THE INVENTION

A communication server provides access to communication facilities. For example, a communication server having a bank of modems may provide subscriber access to the modems for data communication. A communication server may be associated with its own dedicated communication network, or with an existing communication network, such as the public switched telephone network (PSTN).

As communication networks provide greater connectivity and access to information, there is an increasing demand for data communication at higher rates. One solution to provide increased data rates replaces existing twisted pair wiring with high bandwidth media, such as coaxial cables or fiber optic links. Other solutions adopt improved communication techniques using the existing hardware infrastructure. For example, digital subscriber line (XDSL) technology provides higher bandwidth data service over existing twisted pair wiring.

To deliver data service to the subscriber, a communication server may provide a dedicated or permanent connection to its communication facilities. For example, an existing communication server at a central office provides enough communication facilities to simultaneously service all PSTN subscribers. However, all telephone subscribers may not desire data service.

Furthermore, the subscribers that desire data service may not simultaneously access the communication server.

SUMMARY OF THE INVENTION

In accordance with the present invention, the disadvantages and problems associated with communication servers have been substantially reduced or eliminated. In particular, a communication server apparatus and method are disclosed that provide data service to a number of subscribers using a reduced number of XDSL communication facilities.

In one embodiment of the present invention, a communication system includes computers located at subscriber premises, where each computer has a first XDSL modem to communicate information. Twisted pair subscriber lines are coupled to the computers, and each form a local loop. An optional splitter is remotely located from the subscriber premises and coupled to the local loops formed by the twisted pair subscriber lines. The splitter splits each twisted pair subscriber line into a twisted pair data line and a twisted pair telephone line. A communications server coupled to the twisted pair data lines of the splitter has a plurality of second XDSL modems to communicate information with the first XDSL modems using the twisted pair subscriber lines and associated twisted pair data lines. The communication server coupled the second XDSL modems to selected subsets of the twisted pair data lines. The first XDSL modems at the subscriber premises and second XDSL modems at the communications server provide high band with data service using the twisted pair subscriber lines.

Important technical advantages of the present invention include a communication server that provides data service to a number of subscribers using a reduced

number of XDSL communication facilities. Over-subscription of data service is accomplished by selectively coupling a number of twisted pair data lines to a reduced number of XDSL modems. A controller polls the data lines simultaneously or in succession, in groups or individually, to determine which subscribers of the communication system need data service. Upon detecting a need for data service on a selected data line, the controller directs a switch to couple the selected data line to an available modem. The communication server may then provide data service suitable for high bandwidth applications, such as video-on-demand, multimedia, or Internet access.

Another important technical advantage of the present invention includes a communication server that provides over-subscribed XDSL data service using the existing infrastructure of the public switched telephone network (PSTN). Asymmetric digital subscriber line (ADSL), symmetric digital subscriber line (SDSL), high-speed digital subscriber line (HDSL), very high-speed digital subscriber line (VDSL), or other suitable XDSL technology can provide higher bandwidth data service over existing twisted pair wiring. These technologies may support data service simultaneously with traditional telephone service using a separation technique, such as frequency division multiplexing. In one embodiment, a splitter divides each incoming twisted pair subscriber line into a twisted pair phone line and a twisted pair data line. The phone line is coupled to a telephone switch to provide telephone service and the data line is coupled to the communication server to provide over-subscribed XDSL data service. The communication server and splitter may be located at a central office, remote terminal, or other point of presence of the data service provider.

Another important technical advantage of the present invention includes the management and monitoring of XDSL data service provided to subscribers. To accomplish this, the communication server maintains an activity table to determine status information on twisted pair data lines and XDSL modems. In addition, the communication server can track subscriber usage, monitor subscriber information and generate billing and demographic information. In a particular embodiment, an activity detector disconnects a subscriber after a predetermined period of inactivity to release a modem for use by another subscriber.

An important technical advantage of the present invention is the distribution of the switching function to allow scalability of the number of supported data lines and over-subscription of XDSL modems.

A further important technical advantage of the present invention includes isolating the switch from the data lines and subscriber lines. The switch can thereby operate without constraints imposed by technical requirements for interaction with the data lines and subscriber lines. For example, isolation of the switching matrix can allow CMOS switches to be used rather than more expensive solid state relays or mechanical relays.

Yet another important technical advantage of the present invention includes the ability to provide a two-wire isolated interface that can use a single switch to couple a data line to a specific modem. The present invention thus allows one switch per modem per data line configuration. The isolation system of the present invention can transform the data line impedance to an intermediate impedance in order to increase system performance. Other important technical advantages are

readily apparent to one skilled in the art from the following figures, descriptions, and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, and for further features and advantages, reference is now made to the following description taken in conjunction with the accompanying drawings, in which:

FIGURE 1 illustrates a communication system that provides data service;

FIGURE 2 illustrates a communication server in the communication system;

FIGURE 3 illustrates in more detail the controller of the communication server;

FIGURE 4 illustrates in more detail the switch and modem pool of the communication server;

FIGURE 5 illustrates in more detail the transceiver in the controller of the communication server;

FIGURE 6 illustrates in more detail the detector in the controller of the communication server;

FIGURE 7 illustrates an activity table used by the controller of the communication server;

FIGURE 8 is a flow chart of a method for coupling a data line to a modem in the communication server;

FIGURE 9 is a flow chart of a method to decouple a data line from a modem in the communication server;

FIGURE 10A illustrates another implementation of the communication server;

FIGURE 10B illustrates in more detail a line interface device of the communication server of FIGURE 10A;

FIGURE 10C illustrates in more detail the controller of the communication server of FIGURE 10A;

FIGURE 10D illustrates in more detail a detector of the communication server of FIGURE 10A;

FIGURE 10E illustrates in more detail a modem in the modem pool of the communication server of FIGURE 10A;

FIGURE 11A illustrates in more detail an analog filter implementation of a detector of the communication server;

FIGURE 11B illustrates in more detail a tone decoder implementation of a detector of the communication server;

FIGURE 11C illustrates in more detail a digital signal processor implementation of a detector of the communication server;

FIGURE 12 illustrates in more detail a digital switching matrix implementation of the switch of the communication server;

FIGURE 13A illustrates in more detail a frequency multiplexing implementation of the switch of the communication server;

FIGURE 13B is a diagram of frequencies used in the switch of FIGURE 13A;

FIGURE 14A illustrates line interface modules and the modem pool of a distributed switching implementation of the communication server;

FIGURE 14B illustrates in more detail the line interface modules and the modem pool of the communication server of FIGURE 14A;

FIGURE 15 illustrates a functional block diagram of one embodiment of a distributed switching implementation of the communication server;

FIGURE 16 illustrates a block diagram of one embodiment of a line interface module of FIGURE 15;

FIGURE 17 illustrates one embodiment of ATM based transport communication protocols supported on the local

loop and the network interface of the communication server; and

FIGUREs 18A and 18B illustrate a system block diagram for one embodiment of the communication server.

DETAILED DESCRIPTION OF THE INVENTION

FIGURE 1 illustrates a communication system 10 that provides both telephone and data service to a subscriber 12. A station 14 is coupled to subscriber 12 using subscriber line 16. In operation, station 14 provides telephone service, data service, or both telephone and data service to subscriber 12 using subscriber line 16. Subscriber line 16 may support simultaneous telephone and data service using twisted pair wiring.

Subscriber 12 includes a telephone 20 and a computer 22, both coupled to an interface 24. A splitter 25 is coupled to subscriber line 16 and operates to split subscriber line 16 into a twisted pair phone line 26 and a twisted pair data line 28. Phone line 26 is coupled to telephone 20 using interface 24. Similarly, data line 28 is coupled to computer 22 using interface 24. Subscriber 12 refers to one or more components at the subscriber premises shown in FIGURE 1, as well as the user of these components.

Telephone 20 is a traditional telephone transceiver, a cordless telephone transceiver, or any other device suitable for allowing communication over telephone line 26. Computer 22 comprises a mainframe device, mini-frame device, server, desktop personal computer, notebook personal computer, or other suitable computing device having an XDSL modem 30 that communicates data using data line 28. Modem 30 couples to other components of computer 22 using a Peripheral Component Interconnect (PCI) bus, an Industrial Standard Architecture (ISA) bus,

a Personal Computer Memory Card International Association (PCMCIA) interface, or any other suitable technology that provides input/output capability to computer 22. The selection and design of modem 30 for computer 22 may depend on the type or functionality of computer 22, as well as the data service rate supported by data line 28.

Modem 30 transmits and receives data in communication system 10 using any suitable digital subscriber line technology, referred to generally as XDSL. Modem 30 also supports Ethernet, Fast Ethernet, V.35 data protocol, frame relay, asynchronous transfer mode (ATM), switched multi-megabit data service (SMDS), high-level data link control (HDLC), serial line Internet protocol (SLIP), point-to-point protocol (PPP), transmission control protocol/Internet protocol (TCP/IP), or any other appropriate protocol, collectively referred to as digital protocol. For example, computer 22 may include a network interface 31 to receive data from station 14 or to further communicate data to a local area network (LAN), wide area network (WAN), or other suitable network coupled to computer 22 using link 18. In general, modem 30 translates information between the communication protocol supported by communication system 10 and the digital protocol supported by computer 22.

Communication system 10 includes numerous other twisted pair subscriber lines 16 coupled to other subscribers 12. In an exemplary embodiment, station 14 comprises a central office or other device in the public switched telephone network (PSTN) that provides phone and data service to a number of subscribers, with each subscriber 12 including one or more components described above at its premises. The subscribers and subscriber lines in communication system 10 are referred to

collectively in the plural as subscribers 12 and subscriber lines 16.

Interface 24 couples phone line 26 to telephone 20, and data line 28 to computer 22. In one embodiment, interface 24 provides additional couplings to additional telephones 20 and computers 22 at subscriber 12. Splitter 25 is a passive or active splitter that divides subscriber line 16 into phone line 26 and data line 28 of the same type. Throughout this description, phone line 26 and data line 28 may be referred to specifically, or collectively as part of subscriber line 16.

Subscriber line 16 couples subscriber 12 to station 14. Subscriber line 16 comprises twisted pair wiring that is commonly installed at subscriber premises and as the local loop in many public switched telephone networks (PSTNs). Subscriber line 16 may be unshielded twisted pair (UTP), shielded twisted pair (STP), or other suitable type or category of twisted pair wiring made of copper or other suitable material. Phone line 26 and data line 28 associated with subscriber line 16 may be the same or different type or category of twisted pair wiring.

Station 14 includes an optional splitter 50 coupled to subscriber line 16. Like splitter 25 at subscriber 12, splitter 50 at station 14 is a passive or active splitter that divides subscriber line 16 into a twisted pair phone line 52 and a twisted pair data line 54. Phone line 52 and data line 54 associated with subscriber line 16 may be the same or different type or category of twisted pair wiring. In a particular embodiment, a telephone switch 56 at station 14 is coupled to phone line 52 to provide plain old telephone system (POTS) service to subscriber 12. Telephone switch 56 also represents other components in the PSTN or other suitable

voice communication network, such as switches, wireline or wireless links, satellites, microwave uplinks, and other communication facilities to deliver telephone service to subscriber 12.

A communication server 58 is coupled to splitter 50 using data line 54. As described in detail below, communication server 58 manages the provisioning of data service to subscriber 12. Communication server 58 performs off-hook detection on the local loops formed by subscriber lines 16 to determine if subscriber 12 desires data service. Specifically, communication server 58 couples a modem to subscriber line 16 upon detecting a need for data service from computer 22. Communication server 58 tracks subscriber usage, monitors subscriber information, and generates billing and demographic information, as described below.

The data off-hook detector in communication server 58 can use one of several methods to determine whether subscriber 12 should be connected to an XDSL modem. The off-hook detector may monitor direct current voltages, electrical tones, data link frames, or any other protocol or data sequencing to determine whether subscriber 12 needs data access. The off-hook detector in communication server 58 may monitor electrical tones generated by modem 30 while in the process of training, notching, equalizing, or performing any other task that puts electrical tones onto subscriber line 16 and its associated data line 54. Communication server 58 may also detect frames or packets. These frames or packets could be Ethernet, ATM, HDLC, or any suitable data communications frame format. The off-hook detector in communication server 58 could also examine various protocols such as TCP/IP, PPP, or any other suitable network protocol or data stream.

Communication server 58 multiplexes modem digital outputs into a multiplexed digital line 62 for delivery to a router or other network device 60. In one embodiment, multiplexed digital line 62 carries a single bidirectional and multiplexed signal for all subscribers 12 in communication system 10. Signals on multiplexed digital line 62 may support any appropriate digital protocol used by network device 60. A communication network 64, such as a global communication network like the Internet, is coupled to network device 60. Communication network 64 may also include a synchronous optical network (SONET), a frame relay network, an asynchronous transfer mode (ATM) network, a T1, T3, E1, or E3 network, or any other suitable communication network.

One important technical advantage of the present invention is the ability to over-subscribe the XDSL communication facilities of communication server 58 to service an increasing number of subscribers 12 in communication system 10. Communication server 58 may couple to the same number and type of data lines 54 as represented by subscriber lines 16 in communication system 10. For example, if station 14 services one thousand subscribers 12 using twisted pair subscriber lines 16, then data lines 54 coupled to communication server 58 may represent as many as one thousand twisted pair lines.

In one embodiment, not all subscribers 12 in communication system 10 desire access to data service provided by communication server 58. Splitter 50 need not provide a separate data line 54 for those subscribers 12 that only desire phone service from telephone switch 56. As more subscribers 12 desire access to data service, the XDSL communication

capabilities of splitter 50 and communication server 58 may be supplemented in a modular and cost effective manner to meet the demand.

Communication system 10 supports data service over subscriber lines 16 using asymmetric digital subscriber line (ADSL), symmetric digital subscriber line (SDSL), high-speed digital subscriber line (HDSL), very high-speed digital subscriber line (VDSL), or any other suitable technology that allows high rate data service over twisted pair wiring that forms the local loops to subscribers 12. All of these technologies are referred to collectively as XDSL or communication protocol. In one embodiment, subscriber line 16 and components of subscriber 12 and station 14 support communication using ADSL techniques that comply with ANSI standard T1.413. In another embodiment, ADSL communication over subscriber line 16 may be performed using the carrier-less amplitude phase modulation (CAP) technique developed by AT&T Corporation.

In an ADSL communication system, the downlink data rate 32 from station 14 to subscriber 12 is greater than the uplink data rate 34 from subscriber 12 to station 14. This allows high bandwidth communication to subscriber 12, while still providing lower bandwidth communication to station 14. ADSL communication is well-adapted for applications, such as video-on-demand, multimedia, and Internet access, that transfer large volumes of information to subscriber 12 in response to shorter requests for information. In one specific embodiment, downlink data rate 32 is approximately 1.5 Mbps, whereas uplink data rate 34 is approximately 750 kbps. In other embodiments, downlink data rate 32 may be six Mbps or more depending on the specific XDSL technology employed, the quality and length of subscriber line 16, and the

contribution of noise and distortion from other components in communication system 10.

To support high bandwidth data service, local loops formed by subscriber lines 16 may have a maximum length imposed by the XDSL modulation technique or hardware. For example, an existing ADSL implementation operates over local loops of 12,000 feet or less. However, the present invention contemplates, expects, and specifically includes additional communication technologies that extend the maximum length, bandwidth, and quality of communication between subscribers 12 and station 14.

XDSL technology provides data service using existing subscriber lines 16 without interrupting normal telephone service. This is accomplished by a separation technique, such as frequency division multiplexing (FDM), to separate frequencies that provide telephone service from those frequencies that provide data service. Dynamic noise cancellation techniques and a guard band between the data and phone service frequencies ensure reliable and simultaneous access to data and phone service over subscriber line 16. For example, subscriber 12 may simultaneously engage in both a data communication session using computer 22 and a voice conversation using telephone 20.

In operation, communication system 10 provides phone and data service to subscriber 12. Subscriber 12 accesses phone service by using telephone 20 to initiate a call. Upon going off-hook, communication system 10 establishes a circuit between telephone 20 and telephone switch 56 using interface 24, phone line 26, splitter 25, subscriber line 16, splitter 50, and one of phone lines 52. Upon establishing this telephone circuit, subscriber 12 using telephone 20 receives POTS service from telephone switch 56.

To access data service, subscriber 12 turns on computer 22, executes a program, such as an Internet browser, or performs some other affirmative or passive activity that generates a request, command, data packet, electrical tone, or other suitable information or signal that indicates a need for data service. In one embodiment, modem 30 repetitively transmits the need for data service in a request interval, where the request interval comprises the time length of the request and the silent interval until the next request. Alternatively, the need for data service indicated at subscriber 12 may be based on the establishment of a closed circuit between subscriber 12 and station 14 or on one or more analog or digital signal transitions. Modem 30 communicates the need to communication server 58 at station 14 using interface 24, data line 28, splitter 25, subscriber line 16, splitter 50, and one of data lines 54.

As described in detail below, communication server 58 detects the need for data service and selects an XDSL modem at communication server 58 to communicate with XDSL modem 30 in computer 22. Upon establishing a modem connection between modem 30 in computer 22 and a selected modem in communication server 58, subscriber 12 engages in a data communication session with communication network 64 using network device 60. In addition, computer 22 may function as a gateway into communication network 10 for other devices coupled to network interface 31 using link 18.

XDSL technology allows simultaneous use of subscriber line 16 for both phone and data service using the existing twisted pair wiring in communication system 10. In one embodiment, splitter 50, communication server 58, and network device 60 are located at a central office of the PSTN to provide an efficient and modular

provisioning of XDSL data service and voice service to subscribers 12. In a data-only embodiment, communication server 58 and network device 60 may be located at a central office, end office, remote terminal, private premises, or any other location that provides a point of presence of network 64. Splitter 50, communication server 58, and network device 60 may be located at any site or sites remote from subscribers 12 without departing from the scope of the present invention.

FIGURE 2 illustrates in more detail communication server 58. Data lines 54 associated with subscriber lines 16 are coupled to a switch 70. In one embodiment, each data line 54 corresponds to an associated subscriber line 16 and its related subscriber 12. Switch 70 couples selected data lines 54 to output lines 72 that in turn couple to modem pool 74. The format of signals on data lines 54 and output lines 72 is the same as the format of signals on subscriber lines 16. For example, if communication system 10 adopts XDSL technology, signals on data lines 54 and output lines 72 are modulated using XDSL techniques.

Modems in modem pool 74 convert signals in an appropriate XDSL communication protocol into digital data in an appropriate digital protocol on digital lines 76. A multiplexer 78 is coupled to digital lines 76 and combines the signals on digital lines 76 into a fewer number of multiplexed digital lines 62. In one embodiment, multiplexer 78 combines information for delivery to network device 60 using a single multiplexed digital line 62.

A controller 80 is coupled to data lines 54 using a link 82. Controller 80 is also coupled to switch 70 and modem pool 74 using links 84 and 86, respectively. Controller 80 detects a need for data service generated

by subscribers 12 and communicated over subscriber lines 16 to data lines 54. In response, controller 80 using link 84 directs switch 70 to couple a selected subset of data lines 54 to selected output lines 72 that couple to modems in modem pool 74. For example, controller 80 may monitor one thousand data lines 54 to provide XDSL data services using one hundred modems in modem pool 74.

Controller 80 also receives information from modem pool 74 using link 86 to determine status information of modems in modem pool 74. As digital lines 76 become inactive for a predetermined period of time, modem pool 74 detects this inactivity and generates a timeout indication for communication to controller 80. Upon receiving the timeout indication, controller 80 releases the inactive modem in modem pool 74 for later use.

In operation, communication server 58 detects a need for data service on a selected data line 54. This need may be indicated by current voltages, electrical tones, data link frames, packets, or any other suitable analog or digital protocol or data sequencing. Controller 80 detects the need using link 82 and configures switch 70 to provide a coupling between the selected data line 54 and one of the output lines 72 coupled to a selected modem pool 74. The selected modem translates bidirectional communication between a communication protocol on output line 72 and a digital protocol on digital line 76. Multiplexer 78 translates information between digital lines 76 and one or more multiplexed digital lines 62.

FIGURE 3 illustrates in more detail controller 80. Data lines 54 through link 82 are coupled to polling circuitry 100. In one embodiment, polling circuitry 100 includes a number of terminals 102 corresponding to each data line 54. A switch 104 having a conductive probe 106

contacts terminals 102 to sample the signal on the associated data line 54. Polling circuitry 100 may comprise electromagnetic components, such as a relay or switch, solid state circuitry, or both. It should be understood that the present invention embodies any polling circuitry 100 that allows sampling, in succession or simultaneously, one or more data lines 54.

Transceiver 108 receives a selected signal 110 from polling circuitry 100. A detector 112 is coupled to transceiver 108, which in turn is coupled to processor 116. Detector 112 may include a media access controller (MAC) and associated memory to detect and store frames or packets of an appropriate digital protocol. Detector 112 may also include less complicated circuitry to detect current voltages, electrical tones, data bit transmissions, or other analog or digital information generated by transceiver 108.

Transceiver 108 and detector 112 may collectively be represented as modem 115, as indicated by the dashed line. Modem 115 provides an interface between the XDSL communication protocol of communication system 10 and processor 116. Modem 115 also includes similar components and performs similar functions as modem 30 in computer 22 to enable modem 30 and modem 115 to exchange information using XDSL technology. Throughout this discussion, the term detector may refer to detector 112 or collectively modem 115.

A processor 116 is coupled to detector 112 and controls the overall operation of controller 80. A timer 117 is coupled to processor 116. Processor 116 is coupled to input/output circuitry 118, which in turn is coupled to switch 70 and modem pool 74 using links 84 and 86, respectively. Processor 116 is also coupled to switch 104 of polling circuitry 100 using input/output

circuitry 118. In one embodiment, processor 116 controls the data line selection, dwell time, and other suitable parameters of polling circuitry 100.

Processor 116 is also coupled to database 120 that includes a program 121, an activity table 122, a line profile table 124, and a subscriber table 126. Database 120 stores information as one or more tables, files, or other data structure in volatile or non-volatile memory. All or a portion of database 120 may reside at controller 80, within communication server 58, within station 14, or at another location in communication system 10. For example, several communication servers 58 in one or more central offices or other devices of communication system 10 can access database 120 stored in a central location to provide more intelligent management and provisioning of XDSL data service in communication system 10. One or more stations 14 may be coupled together and the resources of their associated communication servers 58 shared using simple network management protocol (SNMP) techniques.

Program 121 contains instructions to be executed by processor 116 to perform the functions of controller 80. Program 121 may reside in database 120 as shown or may be integral to memory components in transceiver 108, detector 112, and/or processor 116. Program 121 may be written in machine code, pseudocode, or other appropriate programming language. Program 121 may include modifiable source code and other version control features that allow modification, debugging, and enhancement of the functionality of program 121.

Activity table 122, described in more detail below with reference to FIGURE 7, maintains status information on data lines 54, switch 70, and output lines 72. In

particular, activity table 122 contains information on inactive and active data lines 54, data lines 54 corresponding to current valid subscribers 16 of XDSL data service, and the mapping performed by switch 70 between data lines 54 and output lines 72. Moreover, activity table 122 includes information that specifies the inactivity of a modem in modem pool 74, the status of a data line 54 as dedicated, and any other suitable information that enables processor 116 to monitor and control the operation of switch 70 and modem pool 74.

Profile table 124 stores profile information on data lines 54. This profile information reflects electrical or physical characteristics of data line 54, its associated subscriber line 16 and data line 28, intervening components such as interface 24, splitter 25, splitter 50, and polling circuitry 100, as well as any other component or factor that effects the performance or electrical characteristics of signals received on data lines 54. Processor 116 may access profile table 124 and provide profile information to transceiver 108 using link 125. Alternatively, transceiver 108 may be a more robust and broadband device that does not need profile information from profile table 124. Processor 116 may also provide profile information to program XDSL modems in modem pool 74 once a coupling is made to a selected data line 54. The existence and complexity of profile information in profile table 124 depends on the requirements of transceiver 108 and XDSL modems in modem pool 74, as well as the complexity of signals that indicate a need for data service from subscriber 12.

Subscriber table 126 stores subscriber information indexed by one or more identifiers of subscriber 12, computer 22, modem 30, subscriber line 16, or other information that associates data line 54 with a

particular subscriber 12. Subscriber table 126 includes subscriber connect times, session duration, session activity, session logs, billing data, subscriber account information, and any other suitable subscriber information. This information may be summarized and additional information included to generate billing and demographic data on subscribers 12 in communication system 10.

For example, subscriber table 126 may maintain summary statistics on the number of subscribers 12 served by communication server 58, the average connect time, load factors, time-of-day connection profiles, and other statistics to assess the communication facilities to be deployed at communication server 58, the over-subscription ratio that can be supported by communication system 10, and other provisioning and management issues. Furthermore, subscriber table 126 may combine subscriber information from one or more communication servers 58 in one or more stations 14 in communication system 10.

Management interface 128 is coupled to processor 116 and database 120 and allows external access to the functionality of processor 116. Management interface 128 is also coupled to database 120, which allows modification of program 121, as well as remote access and modification of information in activity table 122, profile table 124, and subscriber table 126. In one embodiment, the telephone service provider or other entity that operates station 14 or communication system 10 accesses management interface 128 to provide management and control over the operations of controller 80 and communication server 58. For example, the telephone service provider uses management interface 128 to access activity table 122 and/or subscriber table 126 to update the valid subscribers 12 that have access

to communication server 58. A local or remote computer 130 is coupled to program interface 128 using an appropriate data link 132, such as a serial RS-232 link, to provide this management feature.

In operation, modem 30 in computer 22 indicates a need for data service, and communicates this need to an associated data line 54 using interface 24, data line 28, splitter 25, subscriber line 16, and splitter 50. In one embodiment, modem 30 transmits successive requests at a predetermined request interval. Processor 116 accesses activity table 122 to determine which data lines 54 to poll, depending on the active or inactive status of the data line 54, whether subscriber 12 corresponding to data line 54 is a current and valid subscriber, and other appropriate considerations. For example, activity table 122 may indicate valid and non-dedicated subscribers 12 to poll.

Polling circuitry 100 successively or simultaneously polls one or more selected data lines 54, as directed by processor 116, using link 82 to detect a need for data service. For each data line 54 polled, processor 116 may access profile table 124 in database 120 and provide associated profile information to transceiver 108 using link 125. Polling circuitry 100 dwells on each data line 54 for a predetermined polling interval to detect a need. In one embodiment, the polling interval is at least two times a request interval of modem 30.

Upon detecting the need for data service associated with a selected data line 54 from polling circuitry 100, transceiver 108 may translate the information from the selected XDSL communication protocol employed on subscriber line 16 into digital or analog data for detection by detector 112. A media access controller (MAC) in detector 112 may transform serial digital data

from transceiver 108 into a parallel digital format. Detector 112 receives the information translated by transceiver 108, and stores this information in a suitable memory location for access by processor 116. Processor 116 periodically accesses detector 112 to determine if a need for data service has been detected.

Upon detecting a need for data service, processor 116 accesses database 120 to determine the availability and status of modems in modem pool 74. Processor 116 selects an available modem from modem pool 74. Processor 116 then directs switch 70 to make the appropriate coupling between selected data line 54 and output line 72 coupled to the selected modem. Upon establishing coupling between modem 30 in computer 22 at subscriber 12 and a selected modem in modem pool 74, controller 80 continues to monitor the remaining data lines 54 using polling circuitry 100.

Processor 116 can transmit status or connection information to modem 30 in computer 22 using transceiver 108. This may be performed before, during, or after coupling the selected modem in modem pool 74 to data line 54. For example, processor 116 may send acknowledgment information to modem 30 that includes an indication that a modem is or is not available, an identification of the available modem, a time interval before modem 30 should attempt communication with the selected modem in modem pool 74, or any other suitable information. Furthermore, processor 116 may access information from subscriber table 126, such as billing and account information, historical connection information, or other suitable subscriber information, and transmit this information separate to or as part of the acknowledgment information described above.

Processor 116 may also transmit connection information and updated billing and subscriber information to modem 30 at computer 22 using link 86 and the associated XDSL modem in modem pool 74. This information may include the length of the current session, the current balance in the account of subscriber 12, as well as any other suitable information that relates to the account or activity of subscriber 12 with communication server 54. Generally, processor 116 may communicate any suitable information stored at or made available to controller 80 to subscribers 12 using transceiver 108 or the associated modem in modem pool 74.

FIGURE 4 illustrates in more detail switch 70 and modem pool 74 of communication server 58. Data lines 54 are coupled to switch 70, now shown in more detail as a cross-bar or cross-point matrix switch. In this particular embodiment, data lines 54 correspond to lines 150, and output lines 72 correspond to lines 152 in switch 70. The number of lines 150 (n) is greater than the number of lines 152 (m). This allows switch 70 to couple selected data lines 54 to a reduced number of output lines 72 to provide an over-subscription of XDSL data service in communication system 10. For example, switch 70 couples the second of lines 150 to the last of lines 152 by establishing connection 154. Similarly, switch 70 couples the last of lines 150 and the first of lines 152 by establishing connection 156.

Although switch 70 is shown in FIGURE 4 to be a cross-bar or cross-point matrix switch, it should be understood that any device that can couple a number of data lines 54 to a reduced number of output lines 72 may be used. Switch 70 may incorporate electromagnetic components, such as relays and contacts, or may be

implemented in whole or in part using one or more solid state devices.

Modem pool 74 includes XDSL modems 160 associated with output lines 72 from switch 70. Modems 160 translate information between an appropriate XDSL communication protocol on output lines 72 and an appropriate digital protocol on digital lines 76. In one embodiment, modems 160 may be similar in construction and operation to modem 30 at subscriber 12. A detector 162 coupled to modems 160 detects the activity of modems 160 to determine if the line has become inactive for a predetermined interval of time. For example, if one of the modems 160 does not display activity over a five-minute interval, detector 162 generates a timeout indication to notify processor 116 of the inactive modem. Processor 116 releases or decouples the inactive modem for later subscriber sessions. In one embodiment, detectors 162 may include one-shot timers or other retriggerable timers set for a predetermined time interval to detect the inactive status of modems 160.

Detector 162 is a monitoring circuit that passes through the digital output of modems 160 to digital lines 76 for presentation to multiplexer 78. Multiplexer 78 may combine signals from digital lines 76 into a single multiplexed digital line 62. Alternatively, multiplexer 78 may employ any suitable reduction ratio that places signals on digital lines 76 on a fewer number of multiplexed digital lines 62.

Processor 116 may directly communicate with modems 160 using link 164. For example, link 164 allows processor 116 to program modems 160 with profile information retrieved from profile table 124. Link 164 also supports communication between processor 116 and selected subscribers 12 during an active subscriber

session using modems 160. Moreover, link 164 allows processor 116 to monitor the information received from and transmitted to subscribers 12 during a communication session.

In operation, switch 70 couples a selected subset of data lines 54 to output lines 72 in response to signals received from controller 80 using link 84. Each of the output lines 72 is coupled to an associated modem 160 which translates the information formatted in an analog communication protocol, such as XDSL, into an appropriate digital signal. The digital information output from modems 160 passes through detector 162, which monitors the activity on the output line of modems 160. If detector 162 senses inactivity over a predetermined interval, a timeout indication is provided to processor 116 using link 86. Signals on digital lines 76 may be reduced to fewer multiplexed digital lines 62 using multiplexer 78.

FIGURE 5 illustrates in more detail transceiver 108 in controller 80. To receive information, transceiver 108 includes filters and magnetics 170 to condition the signal from selected data line 54. The conditioned signal is provided over differential lines 172 to analog bit pump 174. Bit pump 174 performs the specific demodulation technique for the chosen XDSL communication protocol. For example, bit pump 174 may execute a discrete multi-tone demodulation (DMT) or carrierless amplitude phase demodulation (CAP) to demodulate an XDSL signal on differential lines 172 into a digital stream on line 176. Logic and timing circuitry 178 contains decode logic, timing and synchronization circuitry, steering logic, and other appropriate digital processing circuitry to produce a data signal on receive data line 180 and a corresponding

clock signal on clock line 182 for delivery to detector 112 or processor 116. Detector 112 may include a MAC to support any digital protocol or signal detection that indicates a need for XDSL data service. The data may be in non-return-to-zero format or any other suitable format.

To transmit information, transceiver 108 receives a data signal on transmit data line 184 from detector 112 or processor 116. Using the clock line 182, logic and timing circuitry 178 digitally processes signals received on transmit data line 184 for delivery to analog bit pump 174. Using an appropriate modulation technique, such as DMT or CAP, analog bit pump 174 produces an analog signal for delivery over differential lines 172 to filters and magnetics 170 for transmission over selected data line 54.

FIGURE 6 illustrates in more detail a specific embodiment of detector 112 that includes a MAC 113 and a memory 114. MAC 113 is coupled to receive data line 180 and clock line 182, and translates received data from a serial data format, such as a non-return-to-zero format, into an appropriate parallel digital format. MAC 113 translates the data from the chosen digital protocol and provides the data to memory 114 using data bus 190. MAC 113 also provides an address to memory 114 using address bus 192 to specify the location in memory 114 to store data provided on data bus 190. In addition, MAC 113 provides a write signal to memory 114 using control line 194.

To transmit data, MAC 113 provides a read signal to memory 114 using control line 194, and an associated address of the data to be read using address bus 192. In response, memory 114 provides the requested data on data

bus 190. MAC 113 translates the data into the selected digital protocol for placement on transmit data line 184.

FIGURE 7 illustrates one embodiment of activity table 122 stored in database 120 of controller 80. Processor 116 accesses and modifies entries in activity table 122 to direct the operation of controller 80. In addition, management interface 128 provides external access to activity table 122. For example, a telephone service provider using management interface 128 can add, delete, or otherwise modify entries in activity table 122 to maintain a listing of valid subscribers 12. Database 120 stores some or all of the status information shown in this exemplary activity table 122, as well as other information that may be used by processor 116 to direct the activities of controller 80.

Activity table 122 includes a data line column 200 that contains an address or other appropriate identifier of data lines 54 associated with subscriber lines 16 and their related subscribers 12. Status column 202 indicates the status of data line 54 identified in data line column 200. For example, status column 202 may contain one or more indications that the associated data line 54 is inactive (I), active (A), or dedicated (D). A timeout column 204 indicates whether detector 162 in modem pool 74 has detected a timeout associated with a particular data line 54. A modem column 206 includes an identifier of the modem 160 associated with the corresponding data line 54.

An entry in activity table 122 corresponds to a row that designates a selected data line 54 in data line column 200, the status of the selected data line 54 in status column 202, a timeout indication of the selected data line 54 in timeout column 204, and the modem associated with the selected data line 54 in modem column

206. For example, entry 208 relates to data line "D1" which is inactive. Entry 210 represents data line "D2" which is inactive but dedicated to modem "M1." Entry 212 indicates that data line "D4" is active, coupled to modem "M3," but a timeout indication has been detected.

Subscribers 12 indicated in status column 202 as dedicated may be serviced by communication server 58 in a specific way. Switch 70 in communication server 58 maintains a coupling between data line 54 corresponding to dedicated subscriber 12 and its associated and dedicated modem 160. In this manner, controller 80 need not detect a need for data service or reconfigure the couplings for data line 54 corresponding to dedicated subscriber 12. In this manner, communication server 58 provides the option of a different class of service for a dedicated subscriber 12 that desires uninterrupted access to XDSL communication facilities.

FIGURE 8 is a flow chart of a method performed at controller 80 to couple data lines 54 to modems 160 in modem pool 74. The method begins at step 300 where processor 116 of controller 80 loads activity table 122 from database 120 which contains an entry for each valid subscriber 12 served by communication server 58. Using management interface 128, a telephone service provider may ensure that activity table 122 reflects valid subscribers 12 by monitoring past due accounts, the overuse of data service, successive invalid attempts to access communication server 54, or other factors that may cause subscribers 12 to be invalid. Processor 116 selects the first inactive and non-dedicated data line 54 indicated by the designation "I" in status column 202 of activity table 122. Since switch 70 is configured to continuously couple dedicated subscribers 12 to their dedicated modems 160, processor 116 need not select an

inactive data line 54 that is also dedicated, as indicated by the designation "I/D" in status column 202.

Using input/output circuitry 118, processor 116 directs switch 104 of polling circuitry 100 to couple transceiver 108 to the selected inactive and non-dedicated data line 54 at step 304. If appropriate, processor 116 accesses profile table 124 in database 120 and provides profile information for the selected data line 54 to transceiver 108 using link 125 at step 306. Processor 116 initializes timer 117 with a predetermined polling interval at step 308.

If a need for data service has not been detected by transceiver 108 at step 312, then processor 116 checks timer 117 at step 314. If the polling interval monitored by timer 117 has not expired at step 314, then processor 116 again determines if a need has been detected at step 312. However, if the polling interval monitored by timer 117 has expired at step 314, processor 116 selects the next inactive and non-dedicated data line 54 as indicated in status column 202 of activity table 122 at step 316, and returns to step 304.

If a need for data service is detected at step 312, the associated information may be further processed by detector 112 and placed in memory for access by processor 116 at step 318. Before, during, or after step 318, transceiver 108, detector 112, and/or processor 116 may validate the need for data service. Validation may be performed at a low level, such as a verification of the checksum or detection of an incomplete transmission, or at a higher level, such as a verification of an identifier, password, or other security information that provides access to communication server 58. Validation contemplates any level of validation or security

handshake that confirms that the received need is valid and accepted by controller 80.

Upon selecting an unused modem at step 332, processor 116 generates a command that directs switch 70 to couple the selected data line 54 to the selected modem 160 at step 333. Processor 116 may communicate status or connection information to subscriber 12 using transceiver 108 or the selected modem 160 at step 334. Processor 116 updates activity table 122 at step 336 to indicate that the selected data line 54 is now active and that the selected modem 160 is now being used. Processor 116 directs activity detector 162 to initialize the inactivity interval for the selected modem 160 at step 338. Processor 116 then selects the next inactive and non-dedicated data line 54 in activity table 122 at step 316, and returns to step 304.

FIGURE 9 is a flow chart of a method for monitoring and decoupling modems 160 due to inactivity. It should be understood that the methods described with reference to FIGURES 8 and 9 may be performed simultaneously or in alternative succession by processor 116 to couple and decouple data lines 54 with modems 160. The method begins at step 400 where processor 116 loads activity table 122 which contains an entry for each valid subscriber 12 served by communication server 58. Processor 116 selects a first active and non-dedicated data line 54 as indicated by the designation "A" in status column 202 of activity table 122 at step 402. Since switch 70 is configured to maintain a coupling between dedicated subscribers 12 and their dedicated modems 160, processor 116 need not select an active data line 54 that is also dedicated, as indicated by the designation "A/D" in status column 202.

Processor 116 retrieves timeout status for modem 160 associated with the selected active data line 54 from detector 162 using link 86 and input/output circuitry 118 at step 404. Processor 116 determines if a timeout has occurred for the selected active data line 54 at step 408. If a timeout has not occurred, processor 116 selects the next active and non-dedicated data line 54 as indicated in status column 202 of activity table 122 at step 410, and returns to step 404.

If a timeout has occurred at step 408, processor 116 may communicate status or connection information to subscriber 12 associated with the selected active data line 54 using transceiver 108 or the associated modem 160 at step 412. Processor 116 generates a command to direct switch 70 to decouple the active data line 54 from its associated modem 160 at step 414. Processor 116 updates activity table 122 at step 416 to indicate that data line 54 is now inactive and that the associated modem 160 is available for another subscriber session.

FIGURE 10A illustrates another implementation of communication server 58 in communication system 10. Communication server 58 of FIGURE 10A provides switching at an isolated four-wire interface. As shown in FIGURE 10A, data lines 54 are coupled to and received by a plurality of line interface units 500. Each line interface 500 provides an analog interface, line driver and transformer for processing signals on data lines 54. Each line interface unit 500 is coupled to a switching matrix 502 and communicates with switching matrix 502 across a transmit data pair 504 and a receive data pair 506. Each line interface unit 500 operates to interface between transmit data pair 504 and receive data pair 505 and twisted pair data line 54.

In the implementation of FIGURE 10A, a detector 508 is coupled to each receive data pair 506. Each detector 508 operates to detect a request for service on the associated receive data pair 506 and, upon detection, provides a signal to controller 80 indicating a request for service. Detector 508 is shown in more detail in FIGURE 10D, and implementations of detectors are shown in more detail in FIGURES 11A, 11B and 11C. It should be understood that other implementations can combine polling with multiple detectors to reduce the number of inputs to controller 80 and to reduce the number of detectors. For example, FIGURE 3 shows an implementation using polling circuitry 100 that can be used with the detector in the communication server embodiment of FIGURE 10A.

As shown, switching matrix 502 is coupled to a modem pool 510 and communicates with modem pool 510 across transmit data pairs 512 and receive data pairs 514. Transmit data pairs 512 and receive data pairs 514 contain a number of pairs equal to the number of modems in modem pool 510. As described above, modems in modem pool 510 convert signals in an appropriate XDSL communication protocol into digital data in an appropriate digital protocol on digital lines 76. Multiplexer 78 is then coupled to digital line 76 and provides a multiplexed digital line output 62. Also as described above, controller 80 provides switch control signals 84 to switching matrix 502 and communicates modem selection and control information 86 with modem pool 510.

In operation, each detector 508 detects a request for service on the associated receive data pair 506 and informs controller 80 that a request for service has occurred. Controller 80 then checks which modems in model pool 510 are assigned and which data lines 54 are valid. Controller 80 assigns a modem from modem pool 510

to the requesting data line 54 using switching matrix 502 to connect the associated receive data pair 506 and transmit data pair 504 to the appropriate receive data pair 514 and transmit data pair 512.

A technical advantage of providing switching at a four-wire interface within communication server 58 is that switching matrix 502 is isolated from data lines 54 and subscriber lines 16 by transformers in line interface units 500. Because of this isolation, switching matrix 502 can operate without constraints imposed by technical requirements for interaction with data lines 54 and subscriber lines 16. For example, the isolation of switching matrix 502 allows CMOS switches to be used rather than more expensive solid state relays or mechanical relays.

FIGURE 10B illustrates in more detail line interface device 500 of communication server 58 of FIGURE 10A. Line interface device 500 includes a line protection circuit 520 that is coupled to and receives data line 54. Line protection circuit 54 operates to ensure that activity down stream in communication server 58 does not affect the integrity of data line 54. Line protection circuit 520 is coupled to a magnetics/hybrid unit 522. Magnetics/hybrid unit 522 can comprise a transformer and operates to interface between the data line and an internal transmit data pair 524 and receive data pair 526. Magnetics/hybrid unit 522 also isolates the four-wire interface provided by internal receive data pair 526 and transmit data pair 524 from data line 54.

A line receiver 528 receives receive data pair 526 and drives signals to a receive filter 530. The output of receive filter 530 is receive data pair 506 which is coupled to switching matrix 502 as shown in FIGURE 10A. Similarly, transmit data pair 504 is coupled to a

transmit filter 532 which provides signals to a cable driver 534. Cable driver 534 then drives signals on transmit data pair 524 to magnetics/hybrid unit 522.

FIGURE 10C illustrates in more detail controller 80 of communication server 58 where a plurality of detectors provide indications of a request for service. Controller 80 of FIGURE 10C includes processor 116 and input/output circuitry 118 as discussed above with respect to FIGURE 3. Controller 80 also includes a scanner or processor interrupt circuit 540 which receives the request for service indications from detectors 508 and provides a scanner output or processor interrupt to processor 116. This allows the outputs of a number of detectors 508 to be sampled to provide an appropriate signal to processor 116 when a request for service has been detected. As mentioned above, it should be understood that selection of the number of detectors and the amount of polling can be made as appropriate for the desired application. In one implementation, scanner or processor interrupt circuit 540 comprises a gate array having logic circuitry for generating appropriate interrupt signals to processor 116.

FIGURE 10D illustrates in more detail a detector 508 of communication server 58. As shown, detector 508 includes a receiver circuit 550 and a service request detector 552. Receiver circuit 550 is coupled to a receive data pair 506 and provides an output to service request detector 552. Service request detector 552 then operates to identify a request for service. Upon detection, service request detector 552 provides a signal indicating a request for service to controller 80. For ADSL systems (e.g., CAP and DMT), the request for service can be an initial tone that is a pure sinusoid or a modulated sinusoid. Three implementations of a detector

508 are illustrated in more detail in FIGURES 11A, 11B and 11C and described below.

FIGURE 10E illustrates in more detail a modem 560 in modem pool 510 of communication server 58. Modem 560 is analogous to modem 108 of FIGURE 5 with filters and magnetics 170 removed. Modem 560 includes a bit pump 174 which communicates with switching matrix 502 across receive data pair 526 and transmit data pair 524. Modem 560 does not need to include filters and magnetics 170 because of the functions provided by line interface units 500 to create the four-wire interface described above. Bit pump 174 and logic and timing circuitry 178 otherwise operate as discussed with respect to FIGURE 5. Conceptually, the implementation of FIGURE 10A moves the function of filters and magnetics 170 of modem 108 to line interface units 500 to isolate switching matrix 502 from data lines 54.

FIGURE 11A illustrates in more detail an analog filter implementation of a detector 508 of communication server 58. Detector 508 of FIGURE 11A detects the tone or modulated tone using an analog filter circuit tuned to the distinct frequency used to transmit a subscriber request for service. Detector 508 comprises a differential receiver 570 that is coupled to an associated receive data pair 506. Differential receiver 570 is coupled to and provides a signal to a band pass filter 572. Band pass filter 572 is coupled to a gain device 574 which is coupled to a signal processing circuit 576. The output of signal processing circuit 576 is coupled to a rectifier circuit 578 which is coupled to a low pass filter 580. The output of low pass filter 580 is then provided as one input to a voltage comparator 582. The other input to voltage comparator 582 is connected to a reference voltage 584.

In oper· ·on, detector 508 operates to detect a tone or modulate· ·ne that indicates a request for service on receive data pair 506. Differential receiver 570 produces a voltage output which is filtered by band pass filter 572 and provided to gain device 574. Gain device 574 then amplifies the signal and provides it to signal processing circuit 576. The signal processing circuit 576 processes or demodulates the XDSL signals generated at the customer location that indicate a request for data service. Signal processing circuit 476 provides the signal to rectifier circuit 578 that outputs the signal to low pass filter 580. Low pass filter 580 filters low frequency noise to provide a DC voltage as an input to voltage comparator 582. Voltage comparator 582 compares that DC voltage with reference voltage 584 and outputs a logic high when the DC voltage is greater than reference voltage 584. Reference voltage 584 is set so that voltage comparator 582 signals a request for service only when the appropriate tone or modulated tone is present on receiver data pair 506.

It should be understood that detector 508 of FIGURE 11A, as well as those of FIGURES 11B and 11C, can be connected to polling circuit 100 of FIGURE 3 or other polling circuits to reduce the number of detectors required or to scan the outputs of the detectors. The number of lines that can be polled by a single polling circuit is generally limited by the amount of time that is required by the detector to reliably detect the subscriber request for service.

FIGURE 11B illustrates in more detail a tone decoder implementation of detector 508 of communication server 58. Detector 508 comprises a differential receiver 590 that is coupled to receive data pair 506 and provides an output to a band pass filter 592. Band pass filter 592

is coupled to a gain device 594 which provides an output to a signal processing circuit 596. The signal processing circuit 576 processes or demodulates the XDSL signals generated at the customer location that indicate a request for data service. The output of signal processing device 596 is then coupled to a tone decoder circuit 598. Tone decoder integrated circuit 598 provides an output to controller 80 indicating a request for service upon detection.

In one implementation, tone decoder circuit 598 comprises an integrated circuit, and specifically is an LMC567 tone decoder available from NATIONAL SEMICONDUCTOR. In this implementation, tone decoder circuit 598 includes a phase locked loop detector for identifying the tone or modulated tone that indicates a request for service. The phased locked loop detects when the received tone or modulated tone matches the signaling frequency, and the tone detector circuit responds by signaling a request for service.

FIGURE 11C illustrates in more detail a digital signal processor implementation of detector 508 of the communication server 58. Detector 508 of FIGURE 11C comprises a polling circuit 600 that is coupled to a plurality of receive data pairs 506. Polling circuit selects each receive data pair 506 and connects it to a line receiver 602. Line receiver 602 is coupled to a filter 604 which is coupled to an analog/digital converter 606. Analog/digital converter converts the signal to a digital signal and provides an output to a digital signal processor 608. Upon detection, digital signal processor provides a request for service indication to controller 80.

In the implementation of FIGURE 11C, polling circuitry 600 connects line receiver 602, filter 604,

analog/digital converter 606 and digital signal processor 608 to each line in succession. Digital signal processor 608 reads the data from the analog/digital converter 606 and demodulates or detects the request for service. The dwell time for polling circuitry 600 can be set, for example, such that detector 508 can poll the lines in less than half the duration of the subscriber request for service tone or modulated tone. The number of lines that can be polled by a single digital signal processor 608 is then determined by the amount of time required for digital signal processor 608 to reliably perform the detection algorithm and the duration of the tone described above.

Digital signal processor 608 is programmable to detect the subscriber request for service tone or modulated tone using an appropriate tone detection algorithm or demodulation algorithm. One advantage provided by the detector implementation of FIGURE 11C is this programmability of the algorithm within digital signal processor 608.

It should be understood that the tones used to indicate service in the above description of FIGURES 11A, 11B, and 11C, may be the tone used in standard non-switched applications of XDSL modems, or may be additional tones added specifically to facilitate detection in switching.

FIGURE 12 illustrates in more detail a digital switching matrix implementation of communication server 58. The implementation of FIGURE 12 is appropriate for both a two-wire and four-wire interface to provide digital switching of the modem connections. Communication server 58 of FIGURE 12 includes line interface components and data off-hook detection units 610 that interface with subscriber lines 54 and detect

subscriber requests for service. Request for service indications are then provided to controller 612 for controlling the modem connections.

Each line interface and detection unit 610 is coupled to an associated analog/digital and digital/analog converter 614. Converters 614 are in turn connected to parallel/serial and serial/parallel converters 616. Converters 616 are coupled to a digital multiplexer 618 which operates under control of controller 612 to connect converters 616 to assigned modems in modem pool 620. Modems in modem pool 620 are coupled to a network interface/multiplexer 622 and can be implemented using digital signal processors. As shown, network interface/multiplexer 622 is coupled to and communicates with controller 612. This allows network interface/multiplexer 622 to know which modems and lines are active without having to monitor the communication traffic on the lines.

In operation, incoming communications are converted to digital words by converters 614 and then converted to serial bit streams by converters. The serial bit streams are connected to an assigned modem by digital multiplexer 618. The modems in modem pool 620 then communicate with network interface/multiplexer 622. For outgoing communications, the process is reversed. Serial bit streams from the modems are converted to parallel words and then to analog signals for transmission on data lines 54. This digital switching implementation of communication server 58 can be advantageous for switching of higher frequency XDSL communications.

FIGURE 13A illustrates in more detail a frequency multiplexing implementation for switching modem connections in communication server 58. This frequency multiplexing implementation could be appropriate for

being located at a cable operator as well as a central office of a telephone network. As shown, data lines 54 are coupled to receiver/buffers 630 and transmit/buffers 632. Data off-hook detectors 634 are coupled to the output of receiver/buffers 630 and provide request for service indications to controller 636. For each data line 54, communication server 58 includes a frequency agile modulator 638 and a frequency agile demodulator 640. Each modulator 638 operates to modulate an incoming analog signal at a selectable frequency. In the illustrated embodiment, the frequency is set to one of a plurality of frequencies, f1 to fN, equal in number to the number of available modems. Similarly, each demodulator 640 operates to demodulate at a selectable frequency where the frequency is set to one of the plurality of frequencies, f1 to fN. Associated modulators 638 and demodulators 640 are set to operate at the same frequency.

Modulators 638 provide signals to and demodulators 640 receive signals from a mixer 642. Mixer 642 mixes the signals from modulators 638 and provides the combined signal to demodulators 644. Each demodulator 644 operates to demodulate the incoming signal at one of the frequencies, f1 to fN, as designated by controller 636. Each demodulator 644 is coupled to and provides the demodulated signal to an associated modem 648 in the modem pool. By designating the appropriate frequency, controller 636 effectively connects an assigned a modem 648 to a data line 54.

Outgoing signals are processed in an analogous manner. Each modem 648 provides outgoing analog signals to an associated modulator 646 designated to operate at the same frequency as the associated demodulator 644. Modulators 646 modulate the analog signal and provide the

modulated signal to mixer 642. Mixer 642 combines the modulated signals and provides the combined signal to each demodulator 640. Demodulators 640 demodulate the combined signal to recover the appropriate analog signal at their selected frequency and provide the demodulated analog signal to transmit/buffers 632 for transmission. In this manner, modems 648 are connected to data lines 540 by modulating and demodulating signals at one of the frequencies, f1 to fN.

FIGURE 13B is a diagram of frequencies, f1 to fN, used in the implementation of FIGURE 13A. This results in each of the modems, m1 to mN, being assigned to one of the frequencies, f1 to fN, based upon the frequency for the connected data line 54, as shown. In order to connect a data line 54 to a assigned modem 648, modulators 644 and demodulators 646 are designated to operate at the frequency of the modulator 638 and demodulator 640 for that data line 54.

FIGURE 14A illustrates line interface modules (LIM) 650 and modem pool 652 of a distributed switching implementation of communication server 58. A controller 653 is coupled to line interface modules 650 and to modem pool 652. As shown, a plurality of line interface modules 650 are coupled to the data lines and to modem pool 652. Each line interface module 650 is operable to detect a request for service on the data lines and to connect each of the data lines it receives to each modem in modem pool 652. Controller 653 operates to select a modem from modem pool 652 in response to a detected request for service. Controller 653 then directs the appropriate line interface module 650 to connect the requesting data line to the selected modem. In the illustrated implementation, each line interface module 650 receives N data lines and includes switches to

connect the N data lines to any of the M modems in modem pool 652. In this manner, the switching function is distributed across line interface modules 650 and is scalable as support for more data lines is added. In addition, although a two-wire interface is shown, the architecture of FIGURE 14A can be used at a two-wire or four-wire interface.

Line interface modules 650 allow switching capabilities to be scalable with the desired number of modems and over-subscription. As an example, one implementation has four data lines connected to each line interface module 650 and thirty-two modems in modem pool 652. For a 10:1 over-subscription, this implementation would use 80 line interface modules 650 for connecting 320 data lines to the 32 modems in modem pool 652. In order to double the number of supported data lines, another 80 line interface modules 650 could be added along with another 32 modems. On the other hand, if a 5:1 over-subscription for 32 modems is desired, 40 line interface modules 650 would be used to service 160 data lines.

FIGURE 14B illustrates in more detail line interface modules 650 and modems 660 in modem pool 652. As shown, each line interface module 650 includes a plurality of line interface units 654 that receive one of the N tip and ring data lines. Each line interface device 654 includes magnetics 656 and a plurality of switches 658. In the illustrated implementation, magnetics 656 includes a transformer that receives tip and ring lines of the associated data line. As shown in FIGURE 14B, a T line is then provided to a plurality of switches 658 for connecting the T line to one of M outgoing lines. As shown, the M outgoing lines are equal in number to the number of modems 660 in modem pool 652. Then outputs of

each line interface device 654 are connected together so that line interface module 650 has one output line for each modem 660 in modem pool 652 in addition to one output for the R lines. It should be understood that this can be implemented differentially using a pair of switches to switch the modem to the data line, rather than a single switch and a common R line, to enable switching R lines as well.

Modem pool 652 includes a plurality of modems 660 of which only the front-end portion are shown. Each modem 660 receives two lines from line interface modules 650 using magnetics 662. Because of magnetics 656 and magnetics 662, the switching and connections between line interface devices 654 and modems 660 are isolated from the data lines and from the back-end of modems 660. In one implementation, the connections between line interface modules 650 and modems 660 are accomplished on the back plane of a telecommunications chassis, and the line interface modules 650 and modems 660 are implemented as cards that plug into the back plane. In this implementation, a controller communicates with line interface modules 650 and modems 660 to control switching connections to modems 660.

In general, the communication server of the present invention detects a request for data transport service from a subscriber's XDSL modem, XDSL transceiver unit or other customer premises equipment as well as, for example, from a central office multiplexer. The detected request for service is then used to switch into connection an XDSL transceiver unit located at the central office, remote terminal or other local loop termination point providing, for example, a point of presence for an information service provider (ISP) or corporate network. The request-for-service detection

mechanism allows a large pool of subscribers to be served by a smaller pool of XDSL transceiver units, thereby providing the basis for a cost-effective, massively deployable XDSL service. The request for service detection also makes fault tolerance possible since no subscriber is required to be dependent upon any specific XDSL transceiver unit in the pool.

FIGURE 15 illustrates a functional block diagram of one embodiment of a distributed switching implementation of the communication server, indicated generally at 700. For clarity, one set of line interface modules 702 and POTS filter modules 704 are shown. Larger or smaller numbers of line interface modules and POTS filter modules can be used. In addition, POTS filter modules 704, which can provide the splitting function for voice and data traffic, are optional equipment and are not typically used when the communication server services terminated twisted pair data lines. Communication server 700 also includes line power modules (LPMs) 706 for powering line interface modules 702 and LIM control modules (LCs) 708 for controlling the line interface modules 702. Communication server 700 further includes XDSL transceiver units (xTU-C's) 710, system controllers (SCs) 712, and network interface modules (NIs) 714. In addition, communication server 700 can include expansion units 716.

A number of data buses within communication server 700 are shown in FIGURE 15. Communication server 700 of FIGURE 15 operates through the use of four major bus systems on a backplane of communication server 700: an analog switching bus 718, a digital serial bus 720, serial management buses 722, and a power bus (not shown in FIGURE 15). Each of these buses can support redundancy and fault tolerance. In addition, an analog

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test bus (ATB) can be present for optional analog path testing, a protect bus can be present to allow 1:15 or 1:31 equipment protection for 1:1 deployments, and a busy bus can be used to distribute a busy indication to the line interface modules 702.

In one embodiment, the communication server consists of a multiplexer chassis, one or more optional POTS filter chassis, and one or more optional line interface module (LIM) chassis. In this embodiment, XDSL lines that carry a combined POTS/XDSL signal from the customer premises, can be terminated in a POTS filter shelf, which is a passive unit capable of accepting, for example, up to twenty POTS filter modules 704. These POTS filter modules 704 can contain lightning and power cross protection as well as passive filters which split out any analog POTS connections to the Public Switched Telephone Network (PSTN). Four lines, for example, can be terminated by each POTS module 704, giving the POTS filter shelf a maximum capacity, for example, of 80 subscriber terminations. As mentioned above, where the XDSL lines do not carry both POTS and XDSL signals, the POTS modules 704 are not used.

Wire pairs carrying XDSL service, whether originating from the subscriber or coming from the POTS filter shelf, can then be connected to line interface modules 702. Line interface modules 702 can reside, for example, either in a multiplexer chassis or in a separate LIM chassis. The multiplexer chassis can be capable of supporting up to eight LIM chassis, for a maximum capacity of 640 subscriber lines, or 10:1 oversubscription. The LIM chassis can accept, for example, up to twenty line interface modules 702, with each module 702 terminating four subscriber lines, giving the LIM chassis a capacity of eighty subscribers (at 10:1

oversubscription). The line interface modules 702 can contain line isolation circuitry, digital service request detection circuitry, and an analog switching matrix which performs the concentration of lines to the pool of available XDSL transceiver units 710.

The XDSL signals from the line interface modules 702 can be connected to XDSL transceiver units via analog switching bus 718. The multiplexer chassis can support, for example, up to thirty two XDSL transceiver unit modules 710, with each module 710 containing two XDSL transceiver units, for a total of sixty four XDSL transceiver units. The XDSL transceiver units can be organized in two pools of thirty-two terminations each. Each transceiver can be connected to analog switching bus 718 carrying XDSL signals from the line interface modules 702. Each XDSL port on line interface modules 702 can be connected to one of the thirty two XDSL transceiver units in the assigned pool using a set of analog switches resident on the line interface modules 702.

Two network interface (NI) modules 714 can be provided in the multiplexer chassis, allowing a redundant network interface to be installed if desired. The XDSL transceiver unit modules 710 can be connected to the network interface modules 714 via redundant digital serial point-to-point buses 720, carrying ATM cells on synchronous duplex lines. The network interface modules 714 can statistically multiplex cells to and from XDSL transceiver unit modules 710 in a cell switch architecture. The network interface modules 714 can also processes network signaling data.

Two slots can be provided for system controller (SC) modules 712. One system controller module 712 can be designated as the primary module, and the other system controller module 712 can be installed for redundancy.

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The System controller modules 712 can contain a processor which manages the multiplexer chassis and LIM chassis. Each line interface module 702 and XDSL transceiver unit module 710 can communicate with the System controller module 712 over dual redundant serial management buses 722 for configuration information and to report status. The System controller modules 712 also can provide, for example, both Ethernet and RS-232 management interfaces which can run either SNMP or TL1 protocols respectively. Further, the System controller modules 712 can contain power supply circuitry providing bus bias voltage as well as provide alarm contacts and alarm cut-off functions.

The multiplexer chassis can further contain two expansion unit (EX) slots. Expansion unit units 716 in those slots can be used for a variety of different functions. The expansion unit units 716 can have access to the network interface modules 714 through redundant high-speed serial buses. A separate line power module (LPM) 706 can be used to power line interface modules 702 when they are located in the multiplexer chassis. Line power modules 706 can be placed, for example, in any universal slot and can be redundantly deployed. Further, all modules in communication server 700 can be "hot" insertable. A separate bias supply, generated by the System controller modules 712 or LIM control modules 708, can be used to bias bus logic and allow hitless insertion of all modules in the system. Auto detection of newly inserted modules can then be supported by the System controller modules 712.

Analog switching bus 718 (ASB) is a shared switching bus to which all line interface modules 702 have access. Analog switching bus 718 can consist of individual two-wire connections from the line interface modules 702 to ports for the XDSL transceiver units on modules 710. The

XDSL lines from the customer premises equipment (CPE) are connected to analog switching bus 718 using a matrix of analog switches on respective line interface modules 702. These switches allow each port of line interface modules 702 to be connected to, for example, any one of thirty-two two-wire connections to XDSL transceiver units on modules 710. Sixty four XDSL line terminations, for example, can be supported in the multiplexer chassis in the form of two pools of thirty-two terminations each. Analog switching bus 718 connections can be provided internally on the multiplexer chassis backplane for line interface modules 702 located in the multiplexer chassis. For the LIM chassis, analog switching bus 718 connections can be provided via cable assemblies from the LIM chassis to the multiplexer chassis. The analog switching bus 718 cables can be "daisy-chained" for multiple LIM chassis, as opposed to direct connections from each LIM chassis to the multiplexer chassis, to minimize connectors and cabling.

Digital serial bus 720 provides a path from XDSL transceiver units on modules 710 to network interface modules 714. Each XDSL transceiver unit port can drive two serial data and transmit/receive clock buses towards network interface modules 714, one bus for each network interface module 714, for redundancy. Each network interface module 714 can also drive two serial data buses towards the XDSL transceiver unit ports, and each XDSL transceiver unit can be programmed for which bus to receive by system controller 712.

Serial management bus (SMB) 722 can consist of two buses. Each redundant system controller 712 can drive and operate one of buses 722. The serial management bus 722 can be used to manage all modules on the multiplexer chassis and LIM chassis backplanes. The bus electrical

format can be TTL on the multiplexer chassis backplane and LIM chassis backplane and can be multipoint RS485 from system controllers 712 to LIM controller modules 708 via external cabling. The serial management bus 722 can be an asynchronous bus and can carry a heartbeat message sent on the serial management bus 722 by the system controller modules 712. The other modules can be programmed to automatically switch to the alternate serial management bus 722 if the heartbeat signal is not received. Two control signals issued by the system controller module 712 can be used to determine whether the primary or secondary serial management bus 722 should be used.

XDSL transceiver unit modules 710 provide local loop termination for XDSL service. Each module 710 can support, for example, two XDSL connections to line interface modules 702. In this case, each module 710 can include two XDSL transceiver subsystems, two sets of digital serial data bus interfaces which connect to the network interface modules 714, and a microcontroller and serial management bus interface for configuration and control. The digital serial buses 720 between each XDSL transceiver unit module 710 and the redundant network interface modules 714 can carry demodulated data to the network interface modules 714 and digital data from the network interface modules 714 to be modulated. Data can be, for example, in the form of ATM cells or HDLC-framed packets, and the serial bus can consist of transmit and receive clock and data pairs to each network interface module 714. Each XDSL transceiver unit port on the modules 710 can be programmed by the system controller module 712 for which network interface bus to receive (i.e. which network interface module 714 is active). The microcontroller on the XDSL transceiver unit module 710

can be used to manage communications with the system controller module 712 and to control the XDSL terminations. Rate adaptive decisions, provisioning, performance monitoring, and other control functions can be performed by the microcontroller.

In the illustrated embodiment, system control module 712 is responsible for overall control of the communication server and for gathering of status information. Two system controller modules 712 can be provided for redundancy. In a redundant configuration, the two system controller modules 712 communicate with each other over a dedicated communications bus for sharing database information, self-checking, and on-line/offline control. Data requiring persistent storage, such as provisioning, performance statistics and billing information, can be stored on the system controller module 712 in non-volatile memory. Performance monitoring information can be collected for the network interface modules 714 and for each XDSL line, including information from remote customer premises equipment units.

Network interface modules 714 provide a high-speed connection for aggregated data traffic from the XDSL transceiver units. The network interface modules 714 connect to the XDSL transceiver unit modules 710 via point-to-point serial data buses 720. A high-speed serial interface to subtend host modules (SHMs) can also be provided. In one embodiment, two types of network interface modules 714 are supported: DS3/OC-3 ATM and DS1 ATM. A DS1 Frame Relay interface may also be provided. An OC3/DS3 ATM network interface can support ATM cell traffic at the XDSL transceiver unit interface, and either a 155 Mbit single-mode optical ATM User-Network Interface or a DS3 75 ohm coaxial interface on the

network side. A DS1 ATM network interface can support ATM cell traffic at the XDSL transceiver unit interface, and a 1.544 Mbps DS1 ATM user-network interface on the network side. A DS1 Frame Relay network interface can support a 1.544 Mbit unchannelized DS1 Frame Relay port.

The subtend host module (SHM) is an expansion unit 716 that allows ATM data from multiple multiplexer chassis to be aggregated before being presented to the switched data network, using a technique called subtending. This technique provides full utilization of the ATM switch ports in the network. The subtend host module can contains six DS1 interfaces, and can be used to subtend one to six remote communication servers. The subtend interface can essentially be six DS1 UNI interfaces containing ATM cells, from the remote communication server. DS1 is terminated by the subtend host module and remote cells are sent to the network interface over individual and aggregate 10 Mbit serial connection. Each subtend host module has a serial interface to both network interface modules 714, providing full redundancy. Cell delineation is performed on the network interface 714, and cells are forwarded to the switching matrix in the same manner as cells from the XDSL transceiver unit interfaces.

Line interface module 702 can contain, for example, intra-office line protection/termination, XDSL start tone detection, test bus access, busy bus access, and switching for four XDSL connections. Line interface modules 702 can be located either in the multiplexer chassis for smaller system configurations, or in an LIM chassis for large configurations. A pair of lines from the POTS filter chassis can be routed to each line interface module 702 through the backplane for each interface. The shared analog switching bus 718 between

the line interface modules 702 and the XDSL modem pool carries the switched signal from each active line to an XDSL transceiver unit. Service request detection circuitry detects the presence of start tones generated by the customer premises equipment (CPE) and signals the LIM controller 708 or system controller 712 through the serial management bus 722.

FIGURE 16 illustrates a block diagram of one embodiment of line interface module 702 of FIGURE 15. As shown, line interface module 702 includes a plurality of intra-office protection circuits 730 that receive a two-wire interface for XDSL communications. Intra-office protection circuits 730 are coupled to an analog switch matrix 732. Analog switch matrix 732 connects selected intra-office protection circuits 730 to XDSL transceiver units. In the illustrated embodiment, analog switch matrix 732 connects each of four intra-office protection circuits 730 to one of thirty-two XDSL transceiver units. Line interface module 702 further includes a microcontroller 734 and a start tone detect circuit 736. In this embodiment, analog switch matrix 732 is used to connect each intra-office protection circuit 730 to start tone detect circuit 736 in succession to identify a request for service.

The LIM control modules (LCMs) 708 are responsible for receiving service request detect information from the line interface modules 702, configuring the analog switching matrix 732 under control of the system controller module 712, generating a busy signal for all line interface modules 702 in the chassis, and providing power for the line interface modules 702. One LIM control module 708 can be designated as a primary and another as a redundant back-up. For connection initiation, the LIM control module 708 can poll the line

interface modules 702 to identify any pending service request detection events. The LIM control module 708 can then notify the system controller module 712, which in turn selects an available XDSL transceiver unit. The system controller module 712 then instructs the line interface module 702 to configure the analog switching matrix 732 to connect the requesting port to the selected XDSL transceiver unit. Connection termination notification is provided by the XDSL transceiver unit module 710 to the system controller module 712 upon detecting loss of carrier at the XDSL facility. The system controller module 712 then signals the LIM control module 708 to disconnect the line interface module 702 from the XDSL transceiver unit by clearing the switching matrix connection. Power for the line interface modules 702 can also be provided by the LIM control module 708.

FIGURE 17 illustrates one embodiment of ATM based transport communication protocols supported on the local loop and the network interface of the communication server. Loop protocols refers to the data encapsulation protocols which reside on the local loop interface. It should be recognized that standards bodies are currently formulating a strategy on local loop protocols and the communication server is intended to support various protocol models with minimal hardware impact. PPP over ATM is one implementation for the disclosed communication server architecture. As shown in FIGURE 17, the hardware can consist of a communication server 740 that interconnects a network router 742 and computing devices 744 with an access server 746 for an Internet service provider (ISP) or corporate network 748.

In this implementation, supported protocols are carried over ATM cells. The communication server 740 then becomes an ATM multiplexer switching ATM cells from

the low speed XDSL ports to the high speed network interface port. The communication server 740 network interface can perform this switching independently of the underlying adaptation protocol. All cells can be indiscriminately switched. Specific support for ML1, ML3/4, ML5, OAM, and raw cell formats also can be incorporated into the network interface switching element. RFC1577 compatible IP over ML is a protocol that can be supported over the ATM layer of the XDSL loop. Point to point PVC or SVC connections can be established between the router 742 or device 744 at the customer premise and the access server 746 at the home network. PPP can be used to encapsulate IP, IPX, or Ethernet frames over ATM from the customer premises equipment across the XDSL link to the communication server 740. PPP over ML5 can be encapsulated using RFC1483 guidelines. SNAP/LLC headers can be used to distinguish PPP traffic from other possible traffic types.

The use of PPP allows many protocol encapsulations, including IP and IPX, and bridging using RFC1638. PPP can be carried through the ATM network to the access server 746 located at the corporate or ISP gateway. Authentication can then be performed between the customer premises and the service network using PPP authentication services such as the Password Authentication Protocol (PAP) and the Challenge Handshake Authentication Protocol (CHAP). In this scenario, PPP packets from remote users are transported to the ISP or corporate network 748 for authentication, thus freeing a network provider from authenticating each user to various network destinations. PPP also has the advantage of being relatively protocol independent and may be the wrapper for many networking protocols. In addition, Ethernet bridging may be

supported through the use of ATM Forum LAN Emulation (LANE). LANE allows the bridging of multiple remote users to the home LAN over ATM.

FIGUREs 18A and 18B illustrate a system block diagram for one embodiment of the communication server. As shown, the communication server of FIGUREs 18A and 18B includes a plurality of line interface modules (LIMs) 750 and a plurality of ADSL transceiver units 752 interconnected by dual analog buses 754. ADSL transceiver units 752 are connected to serial buses 756. Each line interface module 750 includes intra-office protection circuits 758, hybrid circuits 760, switch 762 and detect circuit 764. Each ADSL transceiver circuit 752 includes an ADSL chipset 766 (i.e., CAP or DMT) for each transceiver channel, serial bus drivers 768 and other devices 770 (microcontroller, flash RAM). Redundant OC3/DS3 ATM network interface units 772 are connected to ADSL transceiver units 752 by serial buses 756. Each network interface unit 772 includes a plurality of ATM cell delineation circuits 774 connected to ATM cell switch fabric 776. The switch fabric 776 is controlled by OAM/signaling cell access unit 778 and processor 780. A DRAM 782 and a flash memory 784 provide memory space for processor 780. A physical interface 786 and a line interface unit 788 are connected to switch fabric 776 and provide the physical DS3 connection. Redundant system controllers 790 each include serial drivers 792 connected to a processor 794. Relay driver circuits 796 are connected to processor 794 and to alarm relays 798. Receiver circuits 800 also are connected to processor 794 and are connected to OPTO circuits 802. Processor 794 has memory 804 and flash memory 806 provide memory space for processor 794. Processor 794 is further connected to Ethernet interface 808 and to serial

interface 810. System controller 790, network interface 772, ADSL transceiver units 752, and line interface modules 750 operate generally as described above to accomplish the functions of the communication server.

Although the present invention has been described with several embodiments, a myriad of changes, variations, alterations, transformations, and modifications may be suggested to one skilled in the art, and it is intended that the present invention encompass such changes, variations, alterations, transformations, and modifications as fall within the spirit and scope of the appended claims.

WHAT IS CLAIMED IS:

1. A communication system, comprising:

a plurality of computers located at a plurality of subscriber premises, each computer having a first XDSL modem to communicate information;

a plurality of twisted pair subscriber lines coupled to the plurality of computers, each twisted pair subscriber line forming a local loop;

a splitter remotely located from the plurality of subscriber premises and coupled to the local loops formed by the twisted pair subscriber lines, the splitter to split each twisted pair subscriber line into a twisted pair data line and a twisted pair phone line; and

a communication server coupled to the twisted pair data lines of the splitter, the communication server having a plurality of second XDSL modems to communicate information with the first XDSL modems using the twisted pair subscriber lines and associated twisted pair data lines, the communication server to couple the second XDSL modems to selected subsets of the twisted pair data lines, wherein the first XDSL modems at the subscriber premises and the second XDSL modems at the communication server provide high bandwidth data service using the twisted pair subscriber lines.

2. The communication system of Claim 1, further comprising a telephone switch coupled to the twisted pair phone lines of the splitter, the telephone switch to provide telephone service to the subscriber premises using the twisted pair subscriber lines and associated twisted pair phone lines.

3. The communication system of Claim 2, further comprising a plurality of telephones located at the plurality of subscriber premises and coupled to the twisted pair subscriber lines, each telephone operable to receive telephone service provided by the telephone switch.

4. The communication system of Claim 1, further comprising a plurality of second splitters located at the plurality of subscriber premises, each second splitter to split each twisted pair subscriber line into a twisted pair data line and a twisted pair phone line, the twisted pair data line being coupled to the first XDSL modem.

5. The communication system of Claim 1, wherein:

the first XDSL modems communicate information to the second XDSL modems at a first rate; and

the second XDSL modems communicate information to the first XDSL modems at a second rate greater than the first rate.

6. The communication system of Claim 1, wherein the communication server further comprises:

a switch coupled to the twisted pair data lines, the switch to couple a selected subset of the twisted pair data lines to the second XDSL modems; and

a controller coupled to the switch and the twisted pair data lines, the controller to detect a need for data service from at least one computer over an associated twisted pair data line, the controller further to direct the switch to couple the associated twisted pair data line to a selected second XDSL modem in response to detecting the need.

7. The communication system of Claim 1, wherein the communication server further comprises:

a switch coupled to the twisted pair data lines, the switch to couple a selected subset of the twisted pair data lines to the second XDSL modems; and

a controller coupled to the switch and the twisted pair data lines, the controller to poll in succession the twisted pair data lines to detect a need for data service from at least one computer over an associated twisted pair data line, the controller further to direct the switch to couple the associated twisted pair data line to a selected second XDSL modem in response to detecting the need.

8. A communication server coupled to a plurality of twisted pair data lines, each twisted pair data line coupled to an associated twisted pair subscriber line forming a local loop to a subscriber, the communication server comprising:

a plurality of XDSL modems;

a switch coupled to the plurality of XDSL modems, the switch to couple selected subsets of the twisted pair data lines to the XDSL modems;

a detector coupled to the switch and operable to detect a need for data service on a selected twisted pair data line; and

a processor coupled to the detector, the processor to select one of the plurality of XDSL modems in response to detecting the need, the processor further to direct the switch to couple the selected twisted pair data line to the selected XDSL modem, wherein the selected XDSL modem provides high bandwidth data service to the subscriber using the twisted pair subscriber line.

9. The communication server of Claim 8, wherein the plurality of XDSL modems perform data modulation using asymmetric digital subscriber line technology.

10. The communication server of Claim 8, wherein the plurality of XDSL modems to receive information at a first rate and transmit information at a second rate greater than the first rate.

11. The communication server of Claim 8, wherein the switch comprises a cross-point matrix switch.

12. The communication server of Claim 8, further comprising polling circuitry having a plurality of inputs coupled to the twisted pair data lines and a single output coupled to the detector, the polling circuitry to couple in succession the inputs to the output.

13. The communication server of Claim 12, further comprising an activity table coupled to the processor, the activity table specifying a plurality of inactive twisted pair data lines, the processor to access the activity table and to direct the polling circuitry to poll the inactive twisted pair data lines specified in the activity table.

14. The communication server of Claim 8, further comprising an activity table coupled to the processor, the activity table specifying a plurality of active twisted pair data lines, the processor to update the activity table to specify the selected twisted pair data line as one of the active twisted pair data lines.

15. The communication server of Claim 8, further comprising an activity detector coupled to the plurality of XDSL modems, the activity detector to detect a predetermined period of inactivity of the plurality of XDSL modems.

16. The communication server of Claim 8, further comprising a multiplexer coupled to the plurality of XDSL modems, the multiplexer to combine information received from the plurality of XDSL modems into a single multiplexed signal.

17. A method for coupling selected subsets of a plurality of twisted pair subscriber lines to a plurality of XDSL modems in order to off-load high bandwidth data service from a telephone switch, the method comprising:

splitting each twisted pair subscriber line into a twisted pair data line and a twisted pair phone line, each twisted pair subscriber line forming a local loop to a subscriber;

detecting a need for data service on a selected inactive twisted pair data line;

selecting one of the plurality of XDSL modems in response to detecting the need; and

coupling the selected inactive twisted pair data line to the selected XDSL modem, wherein the high bandwidth data service is provided to the subscriber using the selected XDSL modem rather than the telephone switch.

18. The method of Claim 17, further comprising the step of coupling the twisted pair phone lines to the telephone switch to provide telephone service.

19. The method of Claim 17, wherein the plurality of XDSL modems are located at a central office.

20. The method of Claim 17, further comprising:

reading an activity table to identify an inactive twisted pair data line; and

coupling the detector to the identified inactive twisted pair data line.

21. The method of Claim 17, further comprising:
reading an activity table to identify an inactive twisted pair data line;
coupling the detector to the identified inactive twisted pair data line; and
maintaining the coupling between the detector and the identified inactive twisted pair data line for a predetermined interval.

22. The method of Claim 17, further comprising:
reading an activity table to identify an inactive twisted pair data line; and
providing a receiver with a profile of the identified inactive twisted pair data line.

23. The method of Claim 17, further comprising:
reading an activity table to identify an inactive and non-dedicated twisted pair data line; and
coupling the detector to the identified inactive and non-dedicated twisted pair data line.

24. The method of Claim 17, further comprising:
reading an activity table to identify an inactive twisted pair data line associated with a valid and non-dedicated subscriber; and
coupling the detector to the identified inactive twisted pair data line.

25. The method of Claim 17, further comprising the step of updating an activity table to indicate that the selected inactive twisted pair data line is active.

26. The method of Claim 17, wherein the selected inactive twisted pair data line is redesignated an active twisted pair data line, further comprising the following steps to decouple the active twisted pair data line:

detecting a predetermined period of inactivity of the selected XDSL modem; and

decoupling the active twisted pair data line and the selected XDSL modem in response to detecting the predetermined period of inactivity.

27. The method of Claim 17, wherein the selected inactive twisted pair data line is redesignated an active twisted pair data line, further comprising the following steps to decouple the active twisted pair data line:

detecting a predetermined period of inactivity of the selected XDSL modem;

decoupling the active twisted pair data line and the selected XDSL modem in response to detecting the predetermined period of inactivity; and

updating an activity table to indicate that the active twisted pair data line is inactive.

28. The communication system of Claim 1, wherein the number of second XDSL modems is less than the number of twisted pair subscriber lines.

29. The communication server of Claim 8, wherein the number of XDSL modems is less than the number of twisted pair subscriber lines.

30. The method of Claim 17, wherein the number of XDSL modems is less than the number of twisted pair subscriber lines.

31. The communication system of Claim 1, wherein the splitter and the communication server are located at a central office.

32. The communication server of Claim 8, wherein the communication server is located at a central office.-

33. A communication system, comprising:

a plurality of first XDSL modems located at a plurality of subscriber premises;

a plurality of twisted pair lines coupled to the plurality of first XDSL modems, each twisted pair line forming a local loop; and

a communication server coupled to the local loops formed by the plurality of twisted pair lines, the communication server having a plurality of second XDSL modems to communicate information with the plurality of first XDSL modems using the twisted pair lines, the communication server coupling the plurality of second XDSL modems to the plurality of twisted pair lines.

34. The communication system of Claim 33, wherein the plurality of first XDSL modems at the subscriber premises and the plurality of second XDSL modems at the communication server provide high bandwidth data service using the plurality of twisted pair lines.

35. The communication system of Claim 33, further comprising a network device to couple the plurality of second XDSL modems to a communication network.

36. The communication system of Claim 33, wherein the communication server further comprises a multiplexer to multiplex signals received from the plurality of second XDSL modems, the communication system further comprising a network device to couple the multiplexed signals to a communication network.

37. The communication system of Claim 33, wherein the communication server is located at a central office.

38. The communication system of Claim 33, wherein the communication server couples the plurality of second XDSL modems to selected subsets of the plurality of twisted pair lines.

39. The communication system of Claim 33, wherein:

the plurality of first XDSL modems communicate information to the plurality of second XDSL modems at a first rate; and

the plurality of second XDSL modems communicate information to the plurality of first XDSL modems at a second rate greater than the first rate.

40. The communication system of Claim 33, wherein the communication server further comprises:

a switch coupled to the plurality of twisted pair lines, the switch coupling a selected subset of the plurality of twisted pair lines to the plurality of second XDSL modems; and

a controller coupled to the switch and the plurality of twisted pair lines, the controller detecting a need for data service from a first XDSL modem over an associated twisted pair line, the controller directing the switch to couple the associated twisted pair line to a selected second XDSL modem in response to detecting the need.

41. The communication system of Claim 33, wherein the communication server further comprises:

a switch coupled to the plurality of twisted pair lines, the switch coupling a selected subset of the plurality of twisted pair lines to the plurality of second XDSL modems; and

a controller coupled to the switch and the plurality of twisted pair lines, the controller polling the plurality of twisted pair lines to detect a need for data service from a first XDSL modem over an associated twisted pair line, the controller directing the switch to couple the associated twisted pair line to a selected second XDSL modem in response to detecting the need.

42. The communication system of Claim 33, wherein the number of the plurality of second XDSL modems is less than the number of the plurality of twisted pair lines.

43. A communication server coupled to a plurality of twisted pair lines, each twisted pair line forming a local loop to a subscriber, the communication server comprising:

a plurality of XDSL modems;

a switch coupled to the plurality of XDSL modems for coupling the plurality of twisted pair lines to the plurality of XDSL modems;

a detector coupled to the switch for detecting a need for data service on a twisted pair line; and

a processor coupled to the detector for selecting an XDSL modem in response to detecting the need, the processor directing the switch to couple the twisted pair line to the selected XDSL modem.

44. The communication server of Claim 43, wherein the selected XDSL modem provides high bandwidth data service to the subscriber using the twisted pair line.

45. The communication server of Claim 43, wherein the switch couples selected subsets of the plurality of twisted pair lines to the plurality of XDSL modems.

46. The communications server of Claim 43, wherein the plurality of XDSL modems are located at a central office.

47. The communication server of Claim 43, wherein the plurality of XDSL modems perform data modulation using asymmetric digital subscriber line technology.

48. The communication server of Claim 43, wherein the plurality of XDSL modems receive information at a first rate and transmit information at a second rate greater than the first rate.

49. The communication server of Claim 43, wherein the switch comprises a cross-point matrix switch.

50. The communication server of Claim 43, wherein the detector comprises polling circuitry to detect the need for data service on the plurality of twisted pair lines.

51. The communication server of Claim 43, further comprising an activity table coupled to the processor, the activity table specifying a plurality of first twisted pair lines, wherein the processor accesses the activity table and directs the detector to detect a need for data service on the plurality of first twisted pair lines specified in the activity table.

52. The communication server of Claim 43, further comprising an activity detector coupled to the plurality of XDSL modems for detecting a predetermined period of inactivity of the plurality of XDSL modems.

53. The communication server of Claim 43, further comprising a multiplexer coupled to the plurality of XDSL modems for combining information received from more than one of the plurality of XDSL modems into a multiplexed signal.

54. The communication server of Claim 43, wherein the number of the plurality of XDSL modems is less than the number of the plurality of twisted pair lines.

55. A method for coupling a plurality of twisted pair lines to a plurality of XDSL modems, each twisted pair line forming a local loop to a subscriber, the method comprising:

detecting a need for data service on a twisted pair line;

selecting one of the plurality of XDSL modems in response to detecting the need; and

coupling the twisted pair line to the selected XDSL modem.

56. The method of Claim 55, wherein the selected XDSL modem provides high bandwidth data service using the twisted pair line.

57. The method of Claim 55, wherein the plurality of XDSL modems are located at a central office.

58. The method of Claim 55, further comprising:

reading an activity table to identify the twisted pair line;

coupling the detector to the twisted pair line; and

maintaining the coupling between the detector and the twisted pair line for a predetermined interval.

59. The method of Claim 55, further comprising:

reading an activity table to identify the twisted pair line; and

providing a receiver with profile information associated with the twisted pair line.

60. The method of Claim 55, further comprising:

associating the twisted pair line with a valid and non-dedicated subscriber; and

coupling the detector to the twisted pair line.

61. The method of Claim 55, further comprising:

detecting a predetermined period of inactivity of the selected XDSL modem; and

decoupling the twisted pair line and the selected XDSL modem in response to detecting the predetermined period of inactivity.

62. The method of Claim 55, further comprising:

detecting a predetermined period of inactivity of the selected XDSL modem;

decoupling the twisted pair line and the selected XDSL modem in response to detecting the predetermined period of inactivity; and

updating an activity table to indicate that the selected XDSL modem is available.

63. The method of Claim 55, wherein the number of the plurality of XDSL modems is less than the number of the plurality of twisted pair lines.

64. A communication server coupled to a plurality of twisted pair data lines, the communication server comprising:

a plurality of XDSL transceiver units;

a plurality of line interface modules, each line interface module having a plurality of inputs each coupled to a twisted pair data line, and each line interface module having a plurality of outputs each associated with one of the XDSL transceiver units, wherein each line interface module is operable to couple a requesting twisted pair data line to an output associated with a selected XDSL transceiver unit;

a network interface having a plurality of inputs, each input coupled to an associated one of the XDSL transceiver units; and

a system controller coupled to the XDSL transceiver units, to the plurality of line interface modules and to the network interface, the system controller operable:

to select an available XDSL transceiver unit in response to a detected request for data service; and

to direct the line interface module, to which the requesting twisted pair data line is coupled, to connect the requesting twisted pair data line to the selected XDSL transceiver unit.

65. The communication server of Claim 64, wherein each line interface module comprises a plurality of intra-office protection circuits each receiving a twisted pair data line.

66. The communication server of Claim 64, wherein each line interface module comprises an analog switch matrix that operates to couple the requesting twisted pair data line to the output associated with the selected XDSL transceiver unit.

67. The communication server of Claim 64, further comprising an expansion unit coupled to the system controller, the network interface and the plurality of XDSL transceiver units.

68. The communication server of Claim 67, wherein the expansion unit comprises a subtend host module.

69. The communication server of Claim 64, further comprising an LIM control module coupled to the system controller and to the plurality of line interface modules, the LIM control module providing an interface between the system controller and the plurality of line interface modules.

70. The communication server of Claim 64, wherein the outputs of the line interface modules and the XDSL transceiver units are coupled by an analog switching bus.

71. The communication server of Claim 64, wherein the XDSL transceiver units and the network interface are coupled by a digital serial bus.

72. The communication server of Claim 64, wherein the system controller communicates with the line interface modules, the XDSL transceiver units and the network interface across a serial management bus.

73. The communication server of Claim 64, further comprising a redundant system controller.

74. The communication server of Claim 64, further comprising a redundant network interface.

75. A communication server coupled to a plurality of subscriber lines, the communication server comprising:

a plurality of XDSL transceiver units;

a plurality of POTS filter modules, each POTS filter module receiving a plurality of subscriber lines and operable to split each subscriber line into a twisted pair phone line and a twisted pair data line;

a plurality of line interface modules, each line interface module having a plurality of inputs each coupled to a twisted pair data line from an associated POTS filter module, and each line interface module having a plurality of outputs each associated with one of the XDSL transceiver units, wherein each line interface module is operable to couple a requesting twisted pair data line to an output associated with a selected XDSL transceiver unit;

a network interface having a plurality of inputs, each input coupled to an associated one of the XDSL transceiver units; and

a system controller coupled to the XDSL transceiver units, to the plurality of line interface modules and to the network interface, the system controller operable:

to select an available XDSL transceiver unit in response to a detected request for data service; and

to direct the line interface module, to which the requesting twisted pair data line is coupled, to connect the requesting twisted pair data line to the selected XDSL transceiver unit.

76. The communication server of Claim 75, wherein each line interface module comprises a plurality of intra-office protection circuits each receiving a twisted pair data line.

77. The communication server of Claim 75, wherein each line interface module comprises an analog switch matrix that operates to couple the requesting twisted pair data line to the output associated with the selected XDSL transceiver unit.

78. The communication server of Claim 75, further comprising an expansion unit coupled to the system controller, the network interface and the plurality of XDSL transceiver units.

79. The communication server of Claim 78, wherein the expansion unit comprises a subtend host module.

80. The communication server of Claim 75, further comprising an LIM control module coupled to the system controller and to the plurality of line interface modules, the LIM control module providing an interface between the system controller and the plurality of line interface modules.

81. The communication server of Claim 75, wherein the outputs of the line interface modules and the XDSL transceiver units are coupled by an analog switching bus.

82. The communication server of Claim 75, wherein the XDSL transceiver units and the network interface are coupled by a digital serial bus.

83. The communication server of Claim 75, wherein the system controller communicates with the line interface modules, the XDSL transceiver units and the network interface across a serial management bus.

84. A communication server coupled to a plurality of twisted pair data lines, each twisted pair data line coupled to an associated twisted pair subscriber line by a splitter, the communication server comprising:

a plurality of line interface units, each line interface unit coupled to an associated twisted pair data line and coupled to an associated receive data pair and transmit data pair;

a plurality of XDSL modems, each XDSL modem coupled to an associated modem receive data pair and transmit data pair;

a switch coupled to the receive data pair and transmit data pair of each line interface unit, the switch also coupled to the modem receive data pair and transmit data pair of each XDSL modem, the switch operable to couple a selected subset of the receive data pairs and transmit data pairs of the line interface units to the modem receive data pairs and transmit data pairs of the XDSL modems;

a detector operable to detect a need for data service on a receive data pair of a selected line interface unit; and

a controller coupled to the detector and to the switch, the controller operable to select one of the XDSL modems in response to detecting the need for data service, the controller further operable to direct the switch to couple the receive data pair and transmit data pair of the selected line interface unit to the modem receive data pair and transmit data pair of the selected XDSL modem.

85. The communication server of Claim 84, further comprising a plurality of additional detectors, each detector coupled to one of the receive data pairs of the line interface units and operable to detect a need for data service on the receive data pair.

86. The communication server of Claim 84, wherein the controller comprises a processor interrupt circuit coupled to a processor, the processor interrupt circuit coupled to the plurality of detectors and operable to sample outputs of the detectors and to provide a signal indicating a detected request for service to the processor.

87. The communication server of Claim 84, further comprising polling circuitry having a plurality of inputs coupled to the receive data pairs of a plurality of the line interface units and a single output coupled to the detector, the polling circuitry operable to couple in succession the inputs to the output.

88. The communication server of Claim 84, wherein the detector comprises:

a differential receiver coupled to the receive data pair of the selected line interface unit;

a band pass filter coupled to an output of the differential receiver;

a gain device coupled to an output of the band pass filter;

a signal processing circuit coupled to receive an output of the gain device;

a rectifier circuit coupled to an output of the signal processing device;

a low pass filter coupled to an output of the rectifier circuit; and

a voltage comparator coupled to receive as inputs an output of the low pass filter and a reference voltage; the voltage comparator operable to compare the output of the low pass filter to the reference voltage and to provide a signal indicating a detected need for data service.

89. The communication server of Claim 84, wherein the detector comprises:

a differential receiver coupled to the receive data pair of the selected line interface unit;

a band pass filter coupled to an output of the differential receiver;

a gain device coupled to an output of the band pass filter;

a signal processing circuit coupled to receive an output of the gain device; and

a tone decoder circuit coupled to the signal processing circuit, the tone decoder circuit operable to provide a signal indicating a detected need for data service.

90. The communication server of Claim 89, wherein the tone decoder circuit comprises a tone decoder integrated circuit.

91. The communication server of Claim 84, wherein the detector comprises:

polling circuitry having a plurality of inputs coupled to the receive data pairs of selected line interface units and having a single output, the polling circuitry operable to couple in succession the inputs to the output;

a line receiver coupled to the output of the polling circuitry;

a filter coupled to the line receiver;

an analog/digital converter coupled to receive an output of the filter and operable to convert the output from an analog to a digital signal; and

a digital signal processor coupled to receive the digital signal from the analog/digital converter, the digital signal processor operable to provide a signal indicating a detected need for data service.

92. The communication server of Claim 84, wherein each line interface unit comprises:

a line protection circuit coupled to the associated twist pair data line;

a magnetics/hybrid unit coupled to the line protection circuit;

a line receiver coupled to receive an internal receive data pair from the magnetics/hybrid unit;

a receive filter coupled to receive an output of the line receiver and operable to provide the associated receive data pair of the line interface unit;

a transmit filter coupled to receive the associated transmit data pair of the line interface unit;

a cable driver coupled to receive an output of the transmit filter and operable to provide an internal transmit data pair to the magnetics/hybrid unit.

93. The communication server of Claim 84, wherein the XDSL modems perform data modulation using asymmetric digital subscriber line technology.

94. The communication server of Claim 84, wherein the XDSL modems are operable to receive information at a first rate and to transmit information at a second rate greater than the first rate.

95. The communication server of Claim 84, wherein the switch comprises a cross-point matrix switch.

96. The communication server of Claim 84, wherein the switch comprises a digital switching matrix.

97. The communication server of Claim 84, wherein the switch comprises a frequency multiplexing switch.

98. The communication server of Claim 84, further comprising a multiplexer coupled to the XDSL modems, the multiplexer operable to combine information received from the XDSL modems into a single multiplexed signal.

99. A method for coupling a selected subset of a plurality of twisted pair subscriber lines to a plurality of XDSL modems, the method comprising:

splitting each twisted pair subscriber line into a twisted pair data line and a twisted pair phone line;

separating each twisted pair data line into an associated receive data pair and transmit data pair;

detecting a need for data service on a selected receive data pair;

selecting one of the XDSL modems in response to detecting the need for data service; and

coupling the selected receive data pair and associated transmit data pair to a modem receive data pair and transmit data pair of the selected XDSL modem.

100. The method of Claim 99, wherein detecting comprises coupling, in succession, a detector to the receive data pairs.

101. The method of Claim 99, wherein detecting comprises coupling one of a plurality of detectors to each of the receive data pairs.

102. The method of Claim 99, wherein coupling is accomplished using a cross-point matrix switch.

103. The method of Claim 99, wherein coupling is accomplished using digital switching.

104. The method of Claim 99, wherein coupling is accomplished using frequency multiplexing.

105. A communication server coupled to a plurality of twisted pair data lines, each twisted pair data line coupled to an associated twisted pair subscriber line by a splitter, the communication server comprising:

a plurality of line interface components and detectors, each line interface components and detector coupled to an associated twisted pair data line, the line interface components and detectors operable to detect a need for data service on the twisted pair data line and provide a signal indicating a request for service;

a plurality of analog/digital and digital/analog converters, each analog/digital and digital/analog converter coupled to an associated line interface components and detector;

a plurality of parallel/serial and serial/parallel converters, each parallel/serial and serial/parallel converter coupled to an associated analog/digital and digital/analog converter;

a plurality of XDSL modems;

a digital multiplexer coupled to the parallel/serial and serial/parallel converters and coupled to the XDSL modems, the digital multiplexer operable to couple a selected subset of the parallel/serial and serial/parallel converters to the XDSL modems; and

a controller coupled to the detector and to the digital multiplexer, the controller operable to select one of the XDSL modems in response to detecting the need for data service, the controller further operable to direct the digital multiplexer to couple the selected XDSL modem to the parallel/serial and serial/parallel converter associated with the detected need for data service.

106. The communication server of Claim 105, further comprising a network interface/multiplexer coupled to the XDSL modems, the network interface/multiplexer operable to combine information received from the XDSL modems for communication across an attached network.

107. The communication server of Claim 105 wherein the controller is coupled to and operable to communicate with the network interface/multiplexer.

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108. A method for coupling a selected subset of a plurality of twisted pair subscriber lines to a plurality of XDSL modems, the method comprising:

splitting each twisted pair subscriber line into a twisted pair data line and a twisted pair phone line;

converting analog signals received on the twisted pair data lines into incoming parallel digital words and converting outgoing parallel digital words into analog signals for transmission on the twisted pair data lines using first converters coupled to each twisted pair data line;

converting the incoming parallel digital words into incoming serial bit streams and converting outgoing serial bit streams into the outgoing parallel digital words using second converters coupled to the first converters;

detecting a need for data service on a selected twisted pair data line;

selecting one of the XDSL modems in response to detecting the need for data service; and

coupling the selected XDSL modem to a second converter associated with the selected twisted pair data line, the selected XDSL modem receiving the incoming serial bit stream from and providing the outgoing serial bit stream to the associated second converter.

109. The method of Claim 108, wherein coupling is accomplished using a digital multiplexer.

110. The method of Claim 108, wherein detecting comprises coupling, in succession, a detector to the twisted pair data lines.

111. The method of Claim 108, wherein detecting comprises coupling one of a plurality of detectors to each of the twisted pair data lines.

112. A communication server coupled to a plurality of twisted pair data lines, each twisted pair data line coupled to an associated twisted pair subscriber line by a splitter, the communication server comprising:

a plurality of pairs of receiver/buffers and transmit/buffers coupled to associated twisted pair data lines;

a plurality of pairs of frequency agile modulators and demodulators, each frequency agile modulator and demodulator pair coupled to an associated receiver/buffer and transmit/buffer pair, and each frequency agile modulator and demodulator pair set to operate at a unique frequency;

a plurality of pairs of demodulators and modulators, each demodulator and modulator pair having a designatable operation frequency;

a plurality of XDSL modems each coupled to an associated demodulator and modulator pair;

a mixer coupled to the pairs of frequency agile modulators and demodulators and coupled to the pairs of demodulators and modulators, the mixer operable to combine signals from the frequency agile modulators and provide the combined signal to the demodulators, and the mixer further operable to combine signals from the modulators and provide the combined signal to the frequency agile demodulators;

a detector operable to detect a need for data service on a selected twisted pair data line; and

a controller coupled to the detector and to the pairs of demodulators and modulators, the controller operable to select one of the XDSL modems in response to detecting the need for data service, the controller further operable to couple the selected twisted pair data line to the selected XDSL modem by designating the

demodulator and modulator pair associated with the selected XDSL modem to operate at the unique frequency of the frequency agile modulator and demodulator associated with the selected twisted pair data line.

113. The communication server of Claim 112, wherein the communication server is located at a cable system operator.

114. A method for coupling a selected subset of a plurality of twisted pair subscriber lines to a plurality of XDSL modems, the method comprising:

splitting each twisted pair subscriber line into a twisted pair data line and a twisted pair phone line;

for each twisted pair data line, modulating signals received on the twisted pair data line at a unique frequency associated with the twisted pair data line;

mixing the modulated received signals to produce a combined incoming signal;

for each XDSL modem, demodulating the combined incoming signal at a designated frequency associated with the XDSL modem and modulating outgoing signals at the designated frequency;

mixing the modulated outgoing signals from the XDSL modem to produce a combined outgoing signal;

for each twisted pair data line, demodulating the combined outgoing signal at the unique frequency associated with the twisted pair data line to recover signals for transmission on the twisted pair data line;

detecting a need for data service on a selected twisted pair data line;

selecting one of the XDSL modems in response to detecting the need for data service; and

coupling the selected XDSL modem to the selected twisted pair data line by setting the designated frequency associated with the XDSL modem to the unique frequency associated with the selected twisted pair data line.

115. The method of Claim 114, wherein detecting comprises coupling, in succession, a detector to the twisted pair data lines.

116. The method of Claim 114, wherein detecting comprises coupling one of a plurality of detectors to each of the twisted pair data lines.

117. A communication server coupled to a plurality of twisted pair data lines, each twisted pair data line coupled to an associated twisted pair subscriber line by a splitter, the communication server comprising:

a modem pool comprising a plurality of XDSL modems;

a plurality of line interface modules, each line interface module having a plurality of inputs each coupled to a twisted pair data line and having a plurality of outputs each coupled to one of the XDSL modems, and each line interface operable:

to detect a need for data service on a requesting twisted pair data line; and

to couple the requesting twisted pair data line to an output associated with a selected XDSL modem; and

a controller coupled to the XDSL modems and to the plurality of line interface modules, the controller operable to select one of the XDSL modems in response to a detected need for data service, the controller further operable to direct the line interface module to which a requesting twisted pair data line is coupled to couple the requesting twisted pair data line to the output associated with the selected XDSL modem.

118. The communication server of Claim 117, wherein each line interface module comprises a plurality of line interface devices each receiving a twisted pair data line and operable to couple the twisted pair data line to the output associated with the selected XDSL modem.

119. The communication server of Claim 118, wherein each line interface device comprises:

a transformer coupled to the twisted pair data line and providing a T line and an R line as outputs;

a plurality of switches equal in number to the number of XDSL modems, each switch coupled to the T line and operable to couple the T line to one of the XDSL modems; and

the R line coupled to all of the XDSL modems.

120. The communication server of Claim 119, wherein each modem comprises a transformer, the transformer coupled to the R line provided by each line interface device in each line interface module, and the transformer coupled to one switch in each line interface device of each line interface module.

121. The communication server of Claim 117, wherein the line interface modules, modems and controller are implemented as cards that plug into a telecommunications chassis.

122. The communication server of Claim 117, wherein the modem pool comprises thirty-two XDSL modems, and wherein each line interface module has four inputs coupled to twisted pair data lines and thirty-two outputs coupled to XDSL modems.

123. The communication server of Claim 117, wherein the plurality of line interface modules comprises three hundred twenty line interface modules to provide a 10:1 over-subscription.

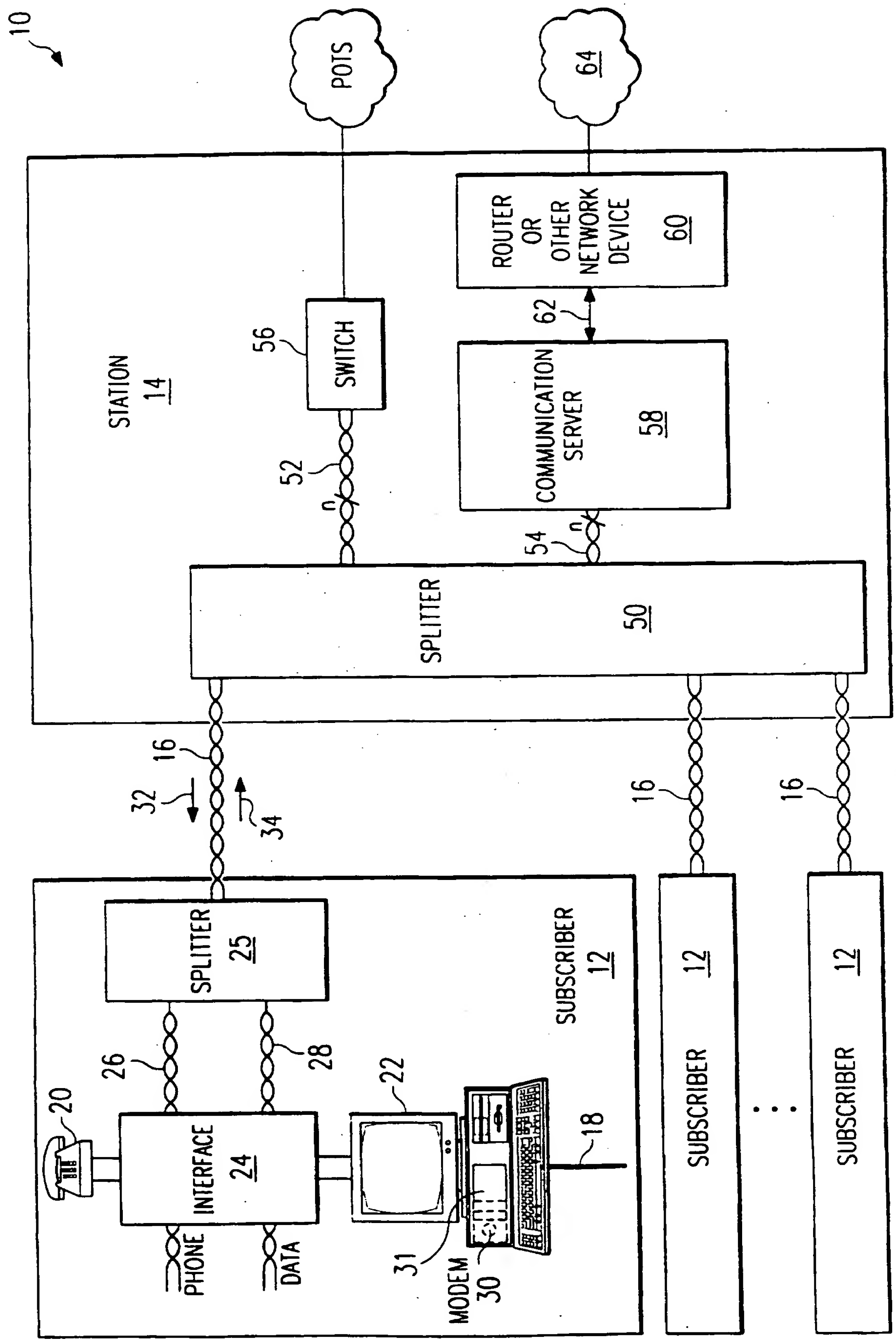
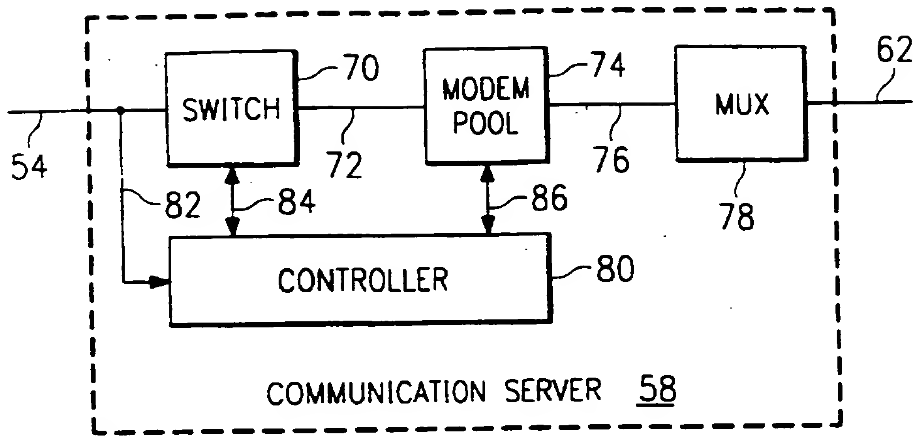


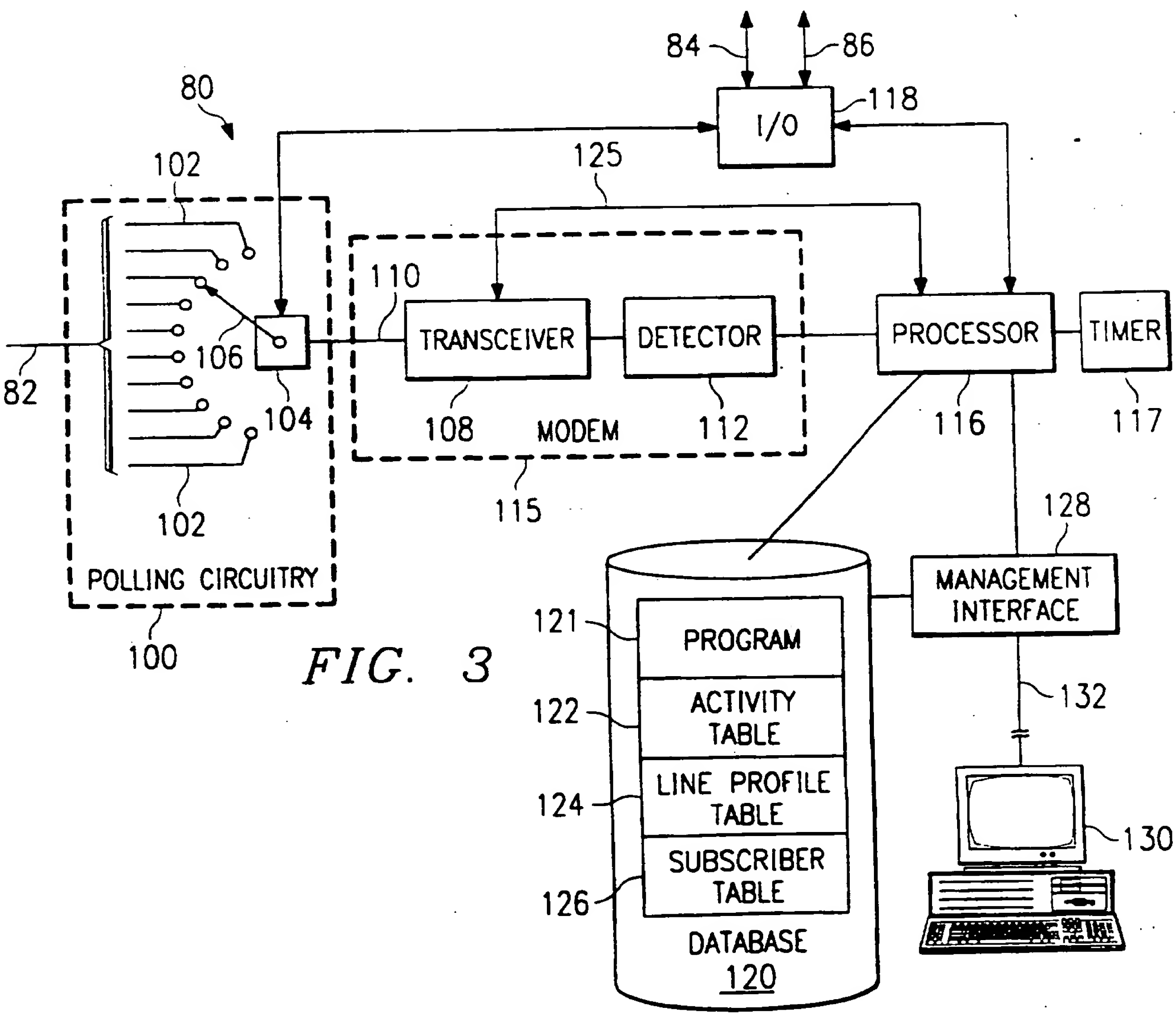
FIG. 1

BNSDOCID: <WO___9737458A2_I_>



SWITCH
70
MODEM POOL
74
MUX
62
54
72
76
82
84
86
78
CONTROLLER
80
COMMUNICATION SERVER 58

FIG. 2



84
86
80
I/O
118
102
125
110
TRANSCEIVER
DETECTOR
PROCESSOR
TIMER
106
82
104
108
MODEM
112
116
117
115
102
128
POLLING CIRCUITRY
MANAGEMENT INTERFACE
100
121
PROGRAM
122
ACTIVITY TABLE
132
124
LINE PROFILE TABLE
130
126
SUBSCRIBER TABLE
DATABASE 120

FIG. 3

FIG. 4

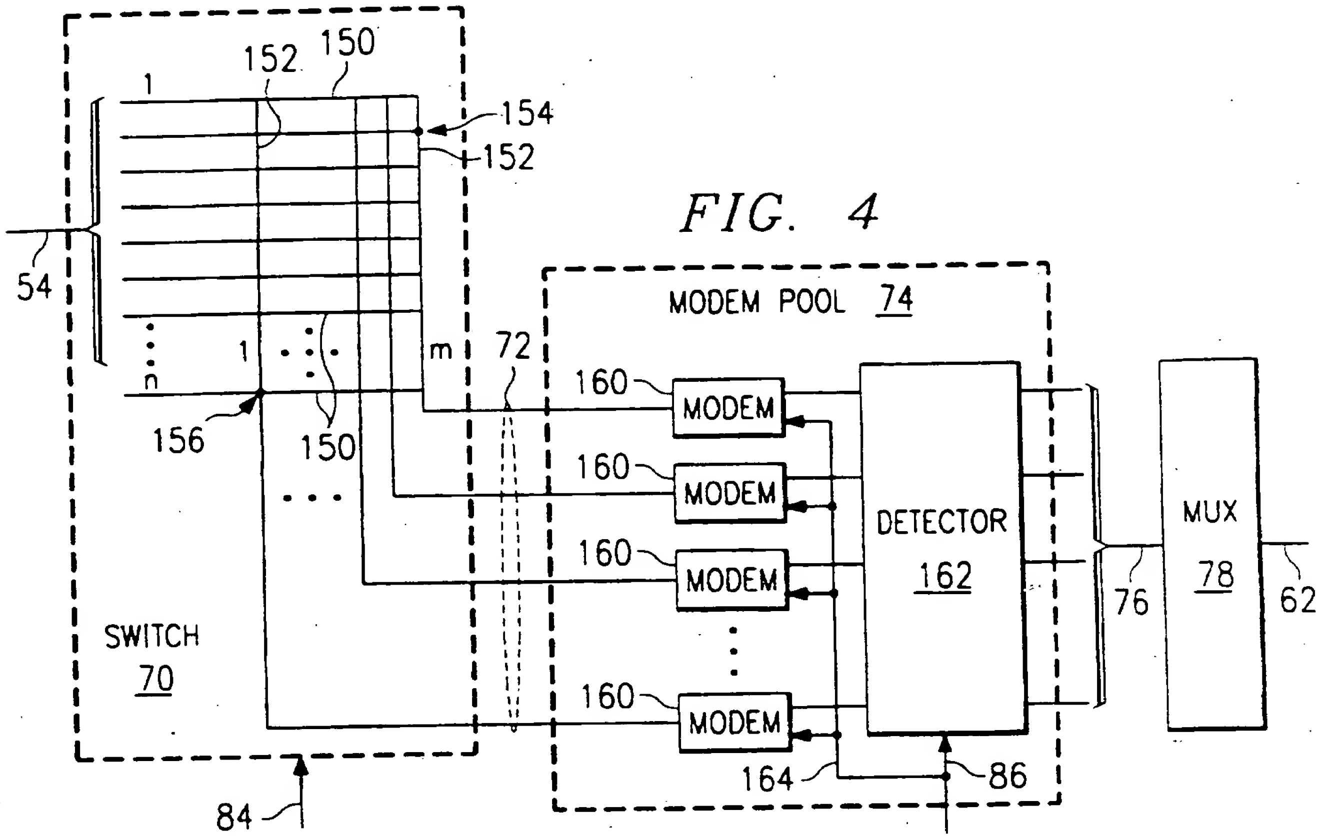


FIG. 5

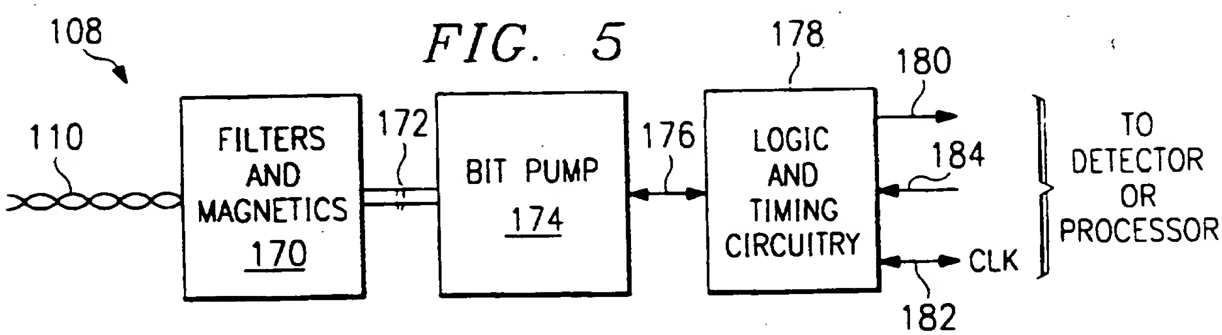
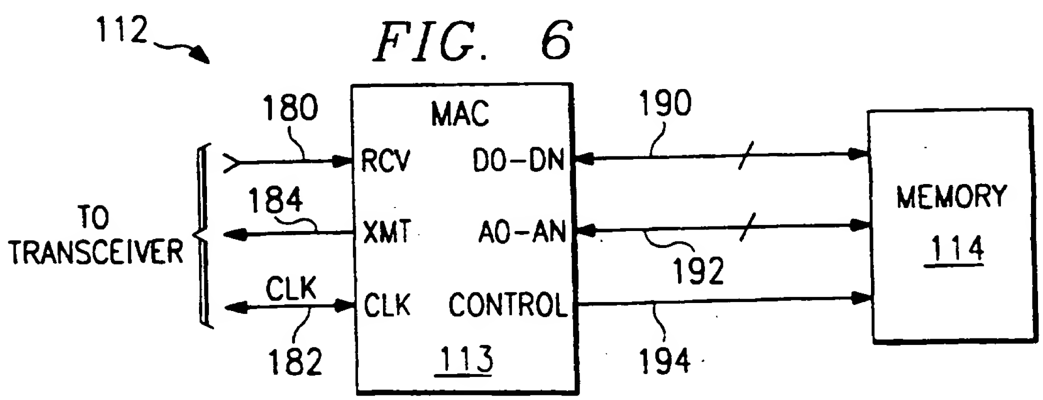


FIG. 6



122

DATA LINE (200)	STATUS (202)	TIMEOUT (204)	MODEM (206)
D1 (208)	I	–	–
D2 (210)	I/D	–	M1
D3	I	–	–
D4 (212)	A	T	M3
D5	I	–	–
D6	I	–	–
D7	A/D	–	M2
D8	A	–	M4
D9	I	–	–
D10	I	–	–

FIG. 7

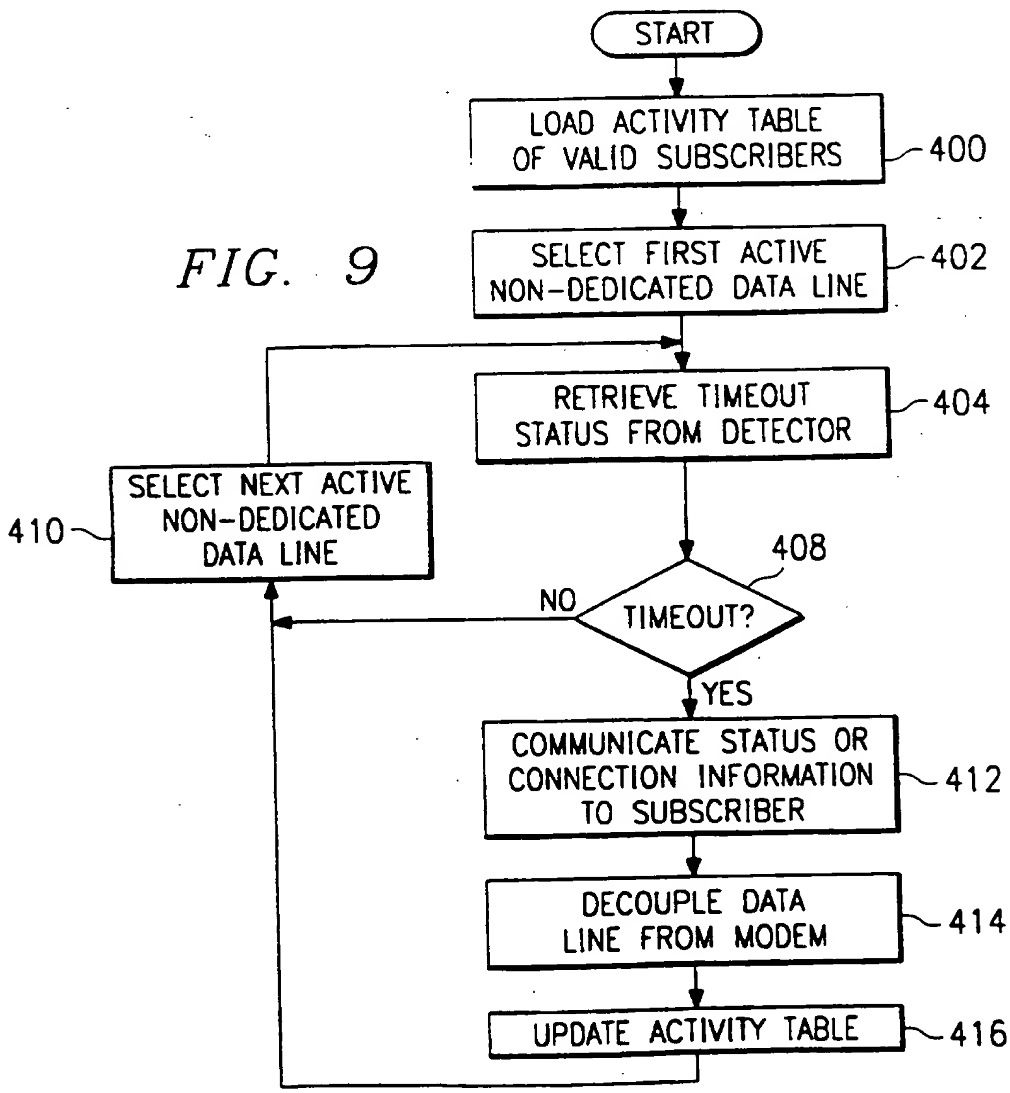
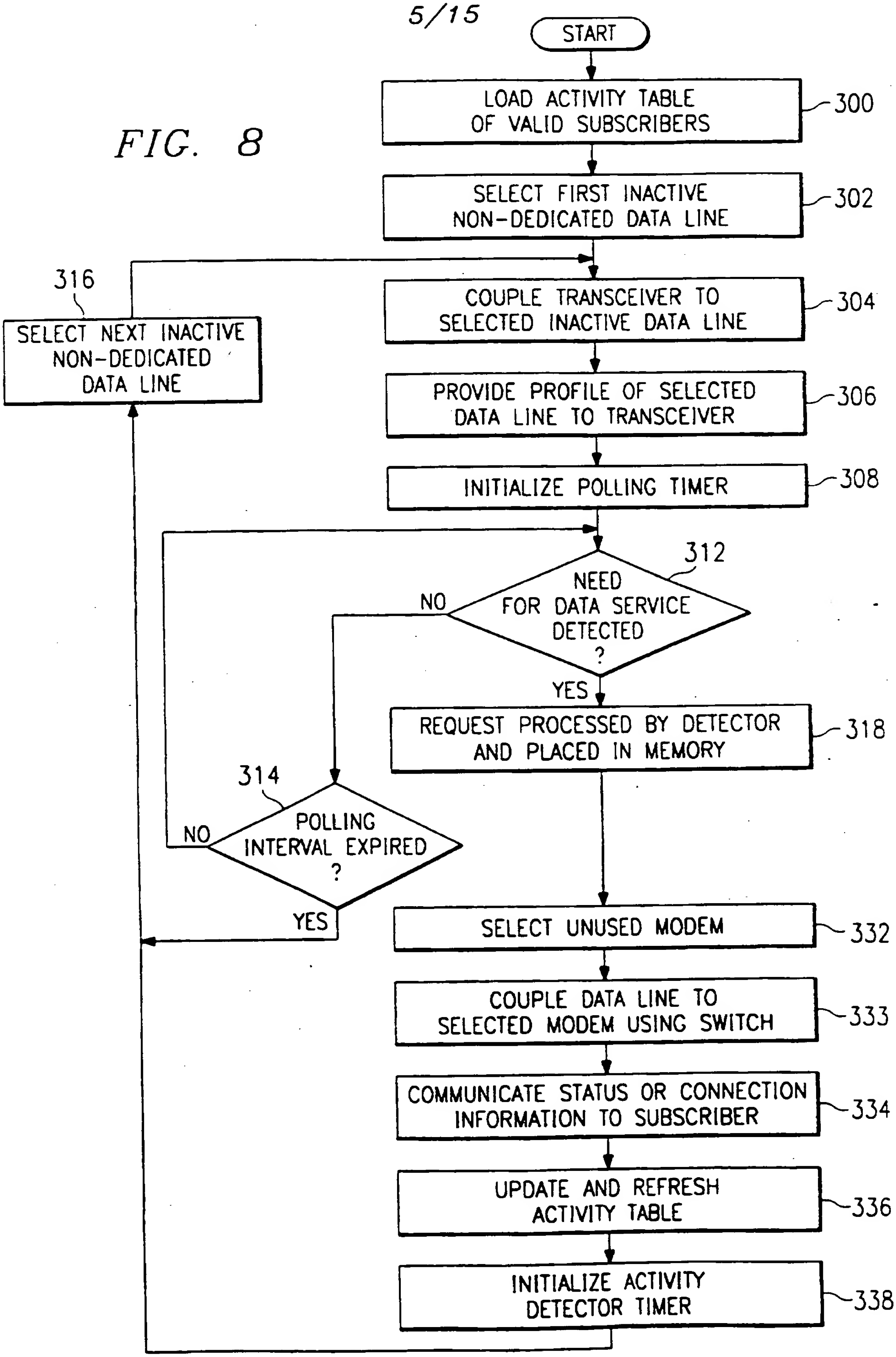


FIG. 9

FIG. 8


START
LOAD ACTIVITY TABLE OF VALID SUBSCRIBERS
300
SELECT FIRST INACTIVE NON-DEDICATED DATA LINE
302
COUPLE TRANSCEIVER TO SELECTED INACTIVE DATA LINE
304
316
SELECT NEXT INACTIVE NON-DEDICATED DATA LINE
PROVIDE PROFILE OF SELECTED DATA LINE TO TRANSCEIVER
306
INITIALIZE POLLING TIMER
308
312
NEED FOR DATA SERVICE DETECTED ?
NO
YES
REQUEST PROCESSED BY DETECTOR AND PLACED IN MEMORY
318
314
POLLING INTERVAL EXPIRED ?
NO
YES
SELECT UNUSED MODEM
332
COUPLE DATA LINE TO SELECTED MODEM USING SWITCH
333
COMMUNICATE STATUS OR CONNECTION INFORMATION TO SUBSCRIBER
334
UPDATE AND REFRESH ACTIVITY TABLE
336
INITIALIZE ACTIVITY DETECTOR TIMER
338

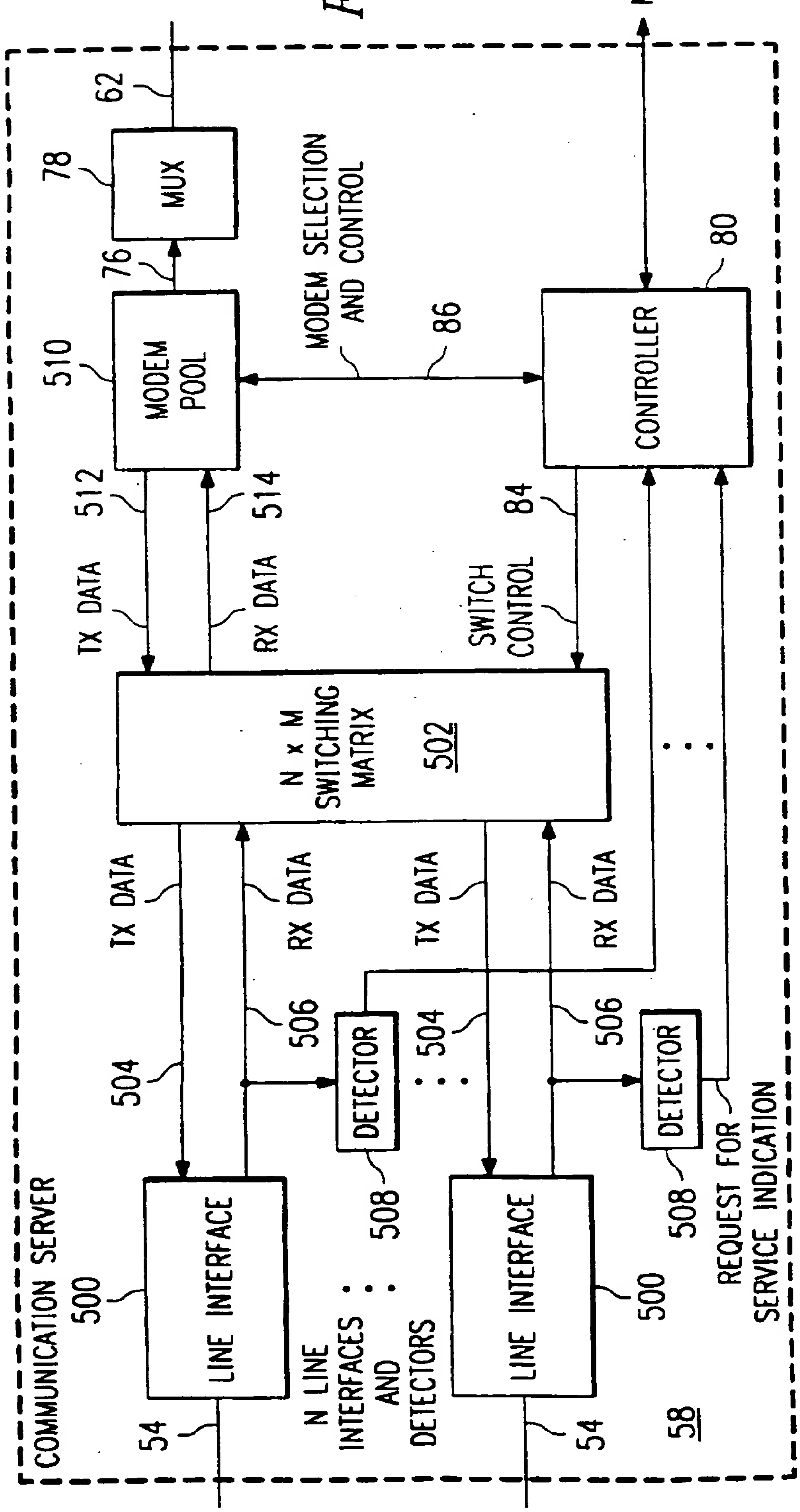


FIG. 10A

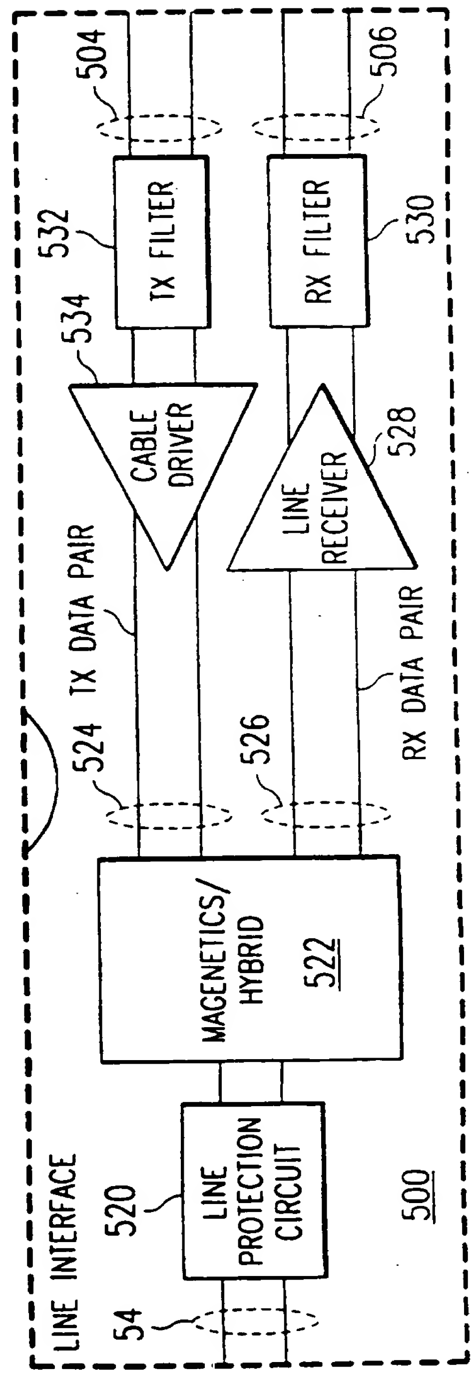


FIG. 10B

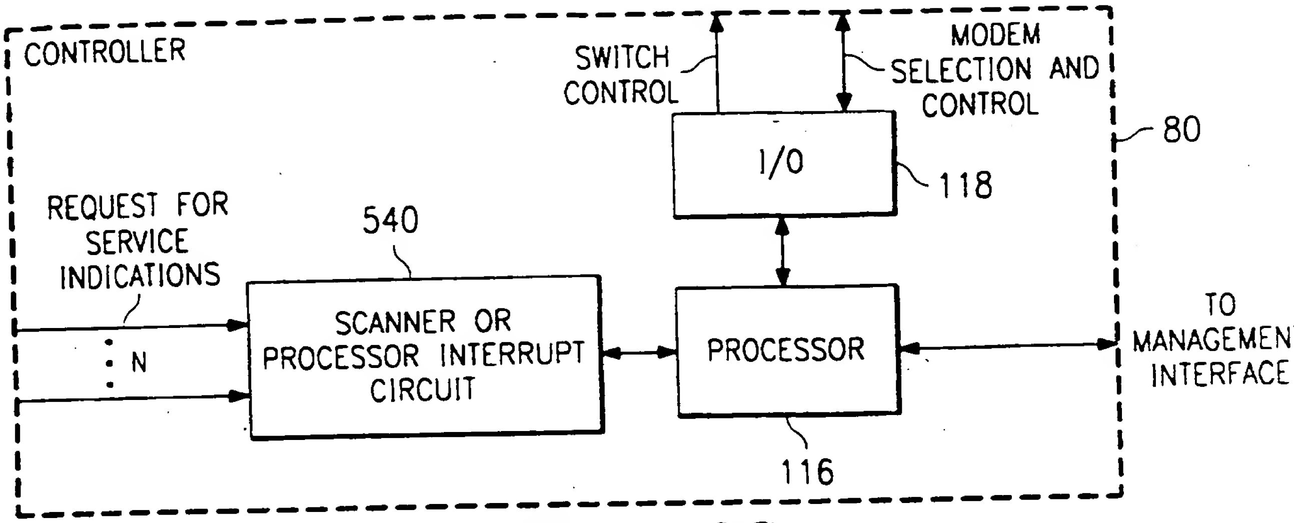


FIG. 10C

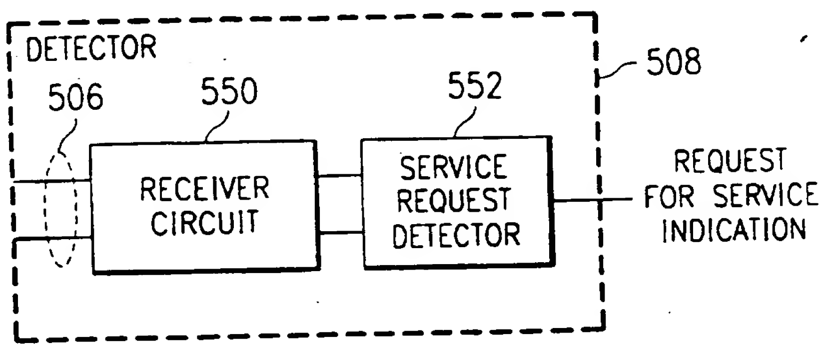


FIG. 10D

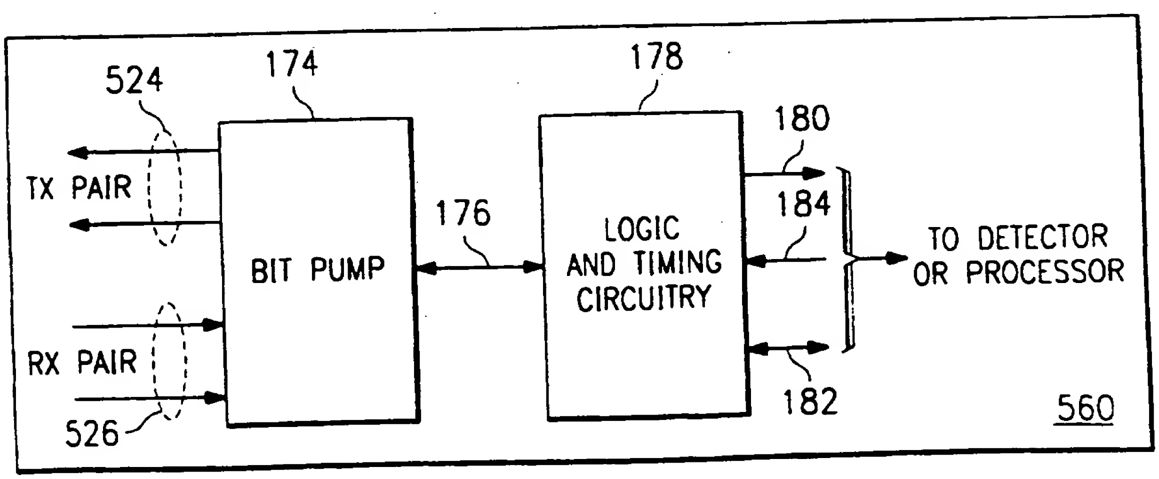


FIG. 10E

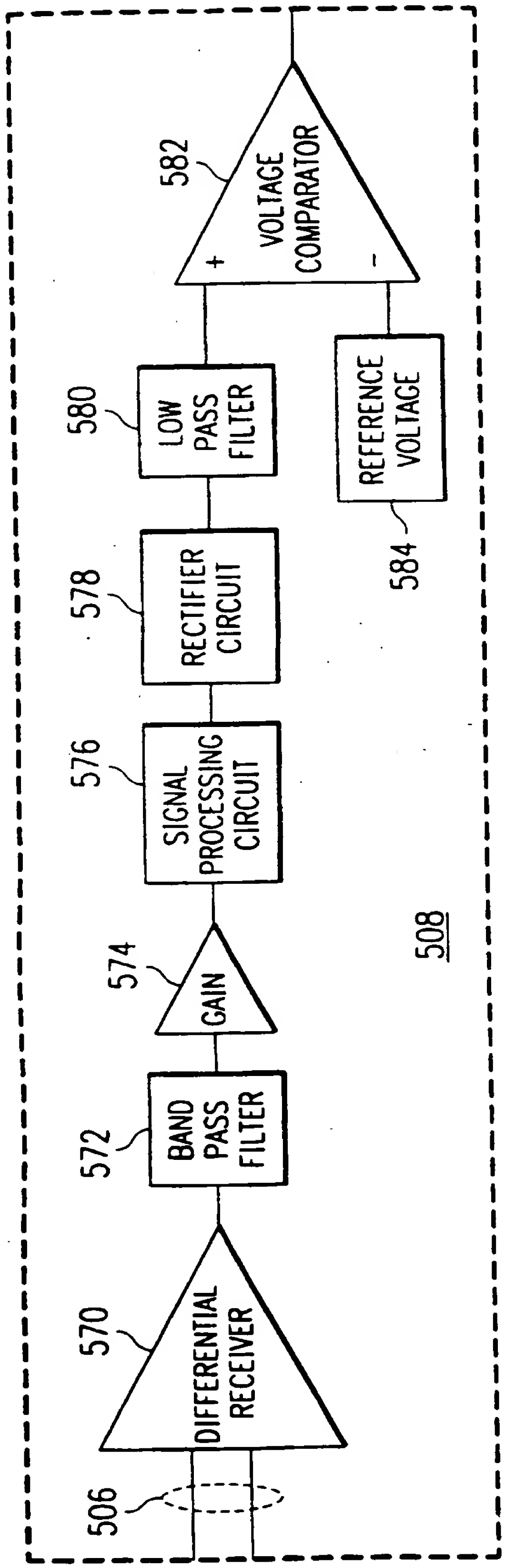


FIG. 11A

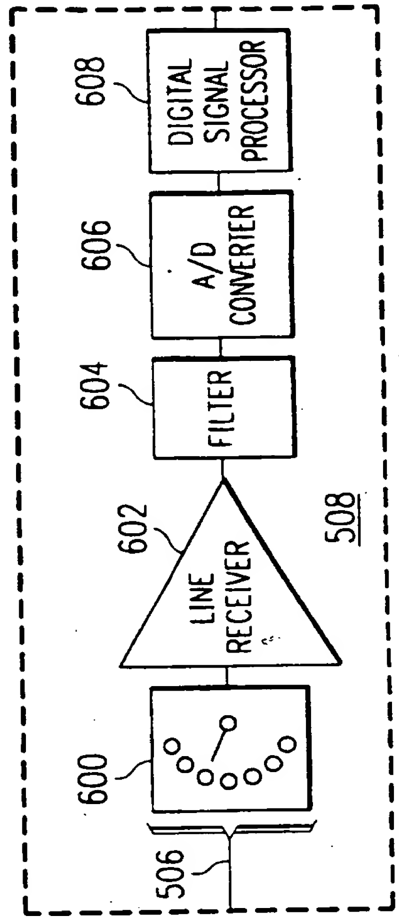


FIG. 11C

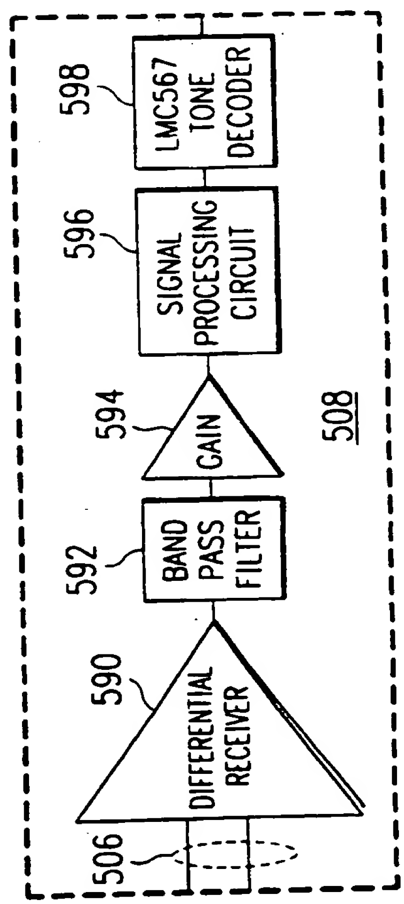


FIG. 11B

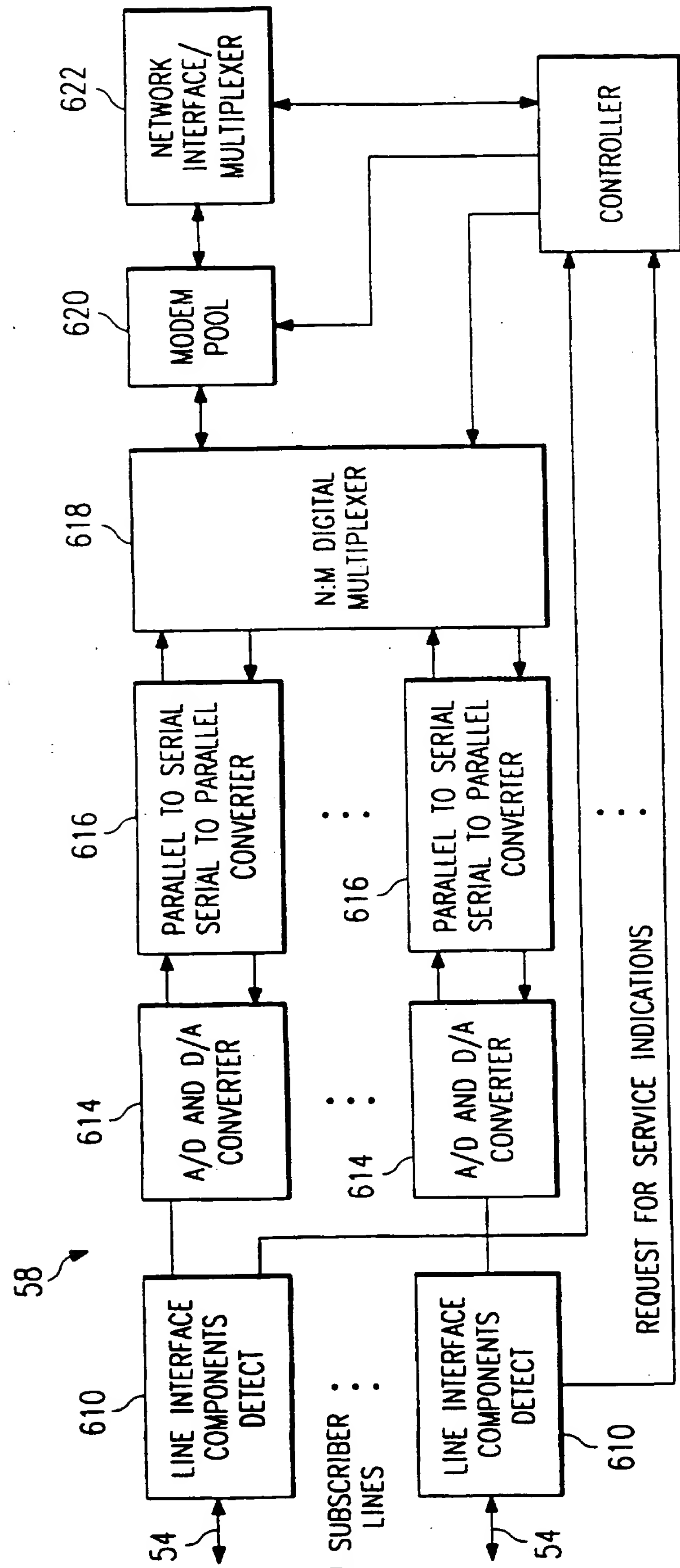


FIG. 12

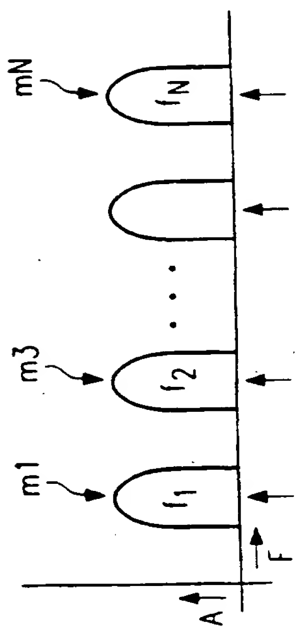
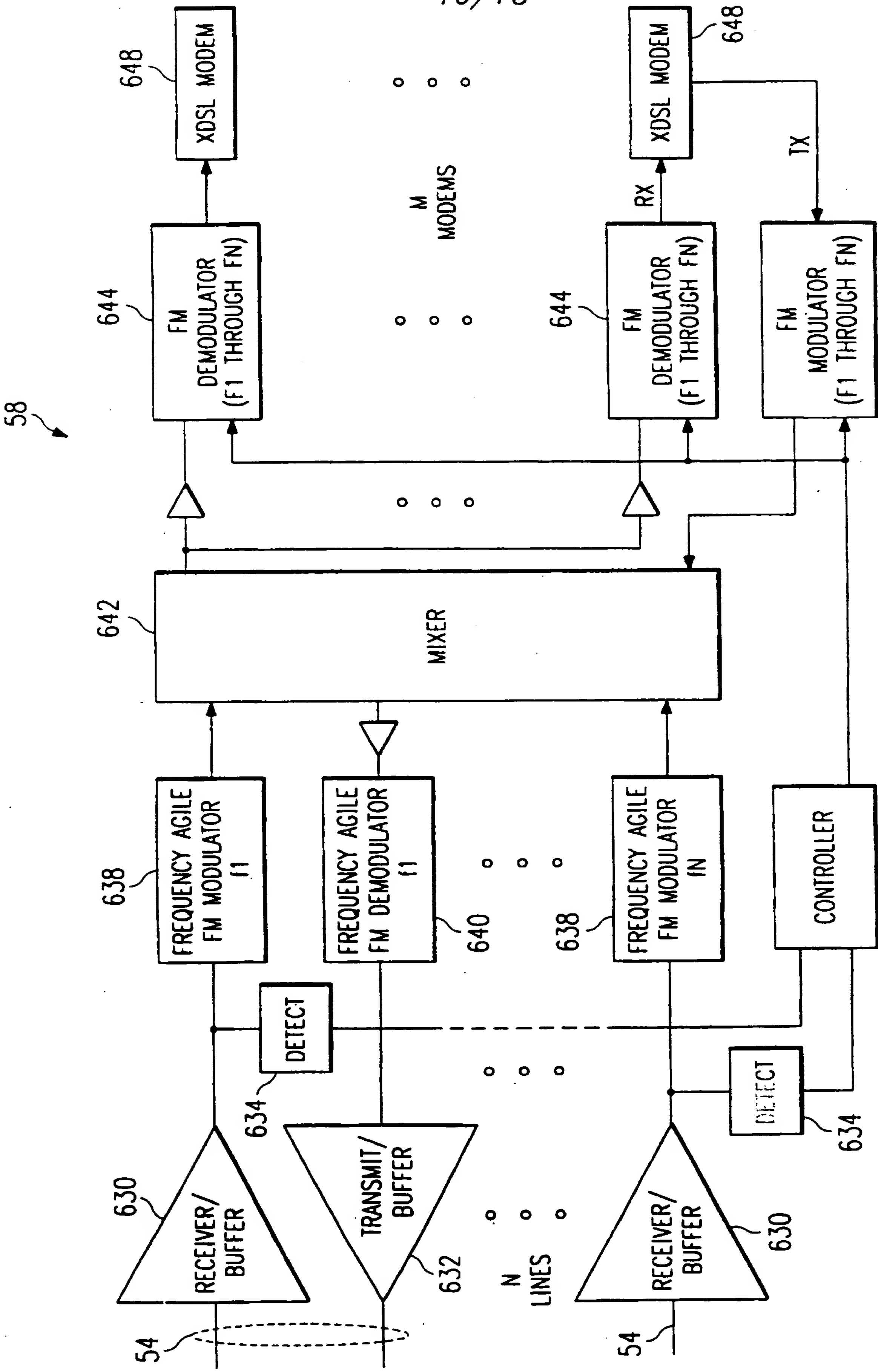


FIG. 13B



58
RECEIVER/ BUFFER
630
TRANSMIT/ BUFFER
632
RECEIVER/ BUFFER
630
54
54
N LINES
DETECT
634
DETECT
634
FREQUENCY AGILE FM MODULATOR f1
638
FREQUENCY AGILE FM DEMODULATOR f1
640
FREQUENCY AGILE FM MODULATOR fN
638
CONTROLLER
636
MIXER
642
FM DEMODULATOR (F1 THROUGH FN)
644
FM DEMODULATOR (F1 THROUGH FN)
644
FM MODULATOR (F1 THROUGH FN)
646
XDSL MODEM
648
XDSL MODEM
648
M MODEMS
RX
TX

FIG. 13A

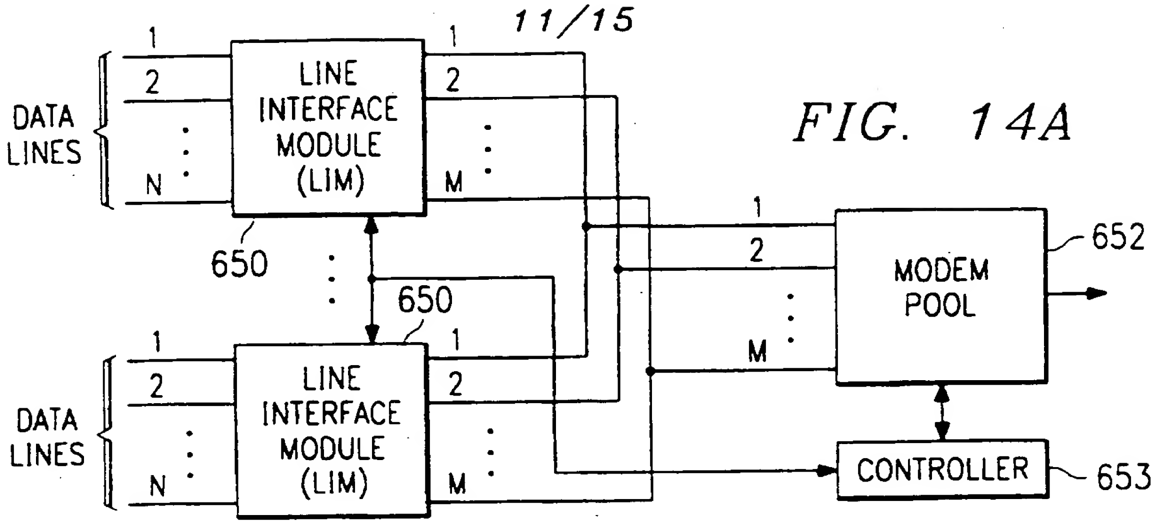


FIG. 14A

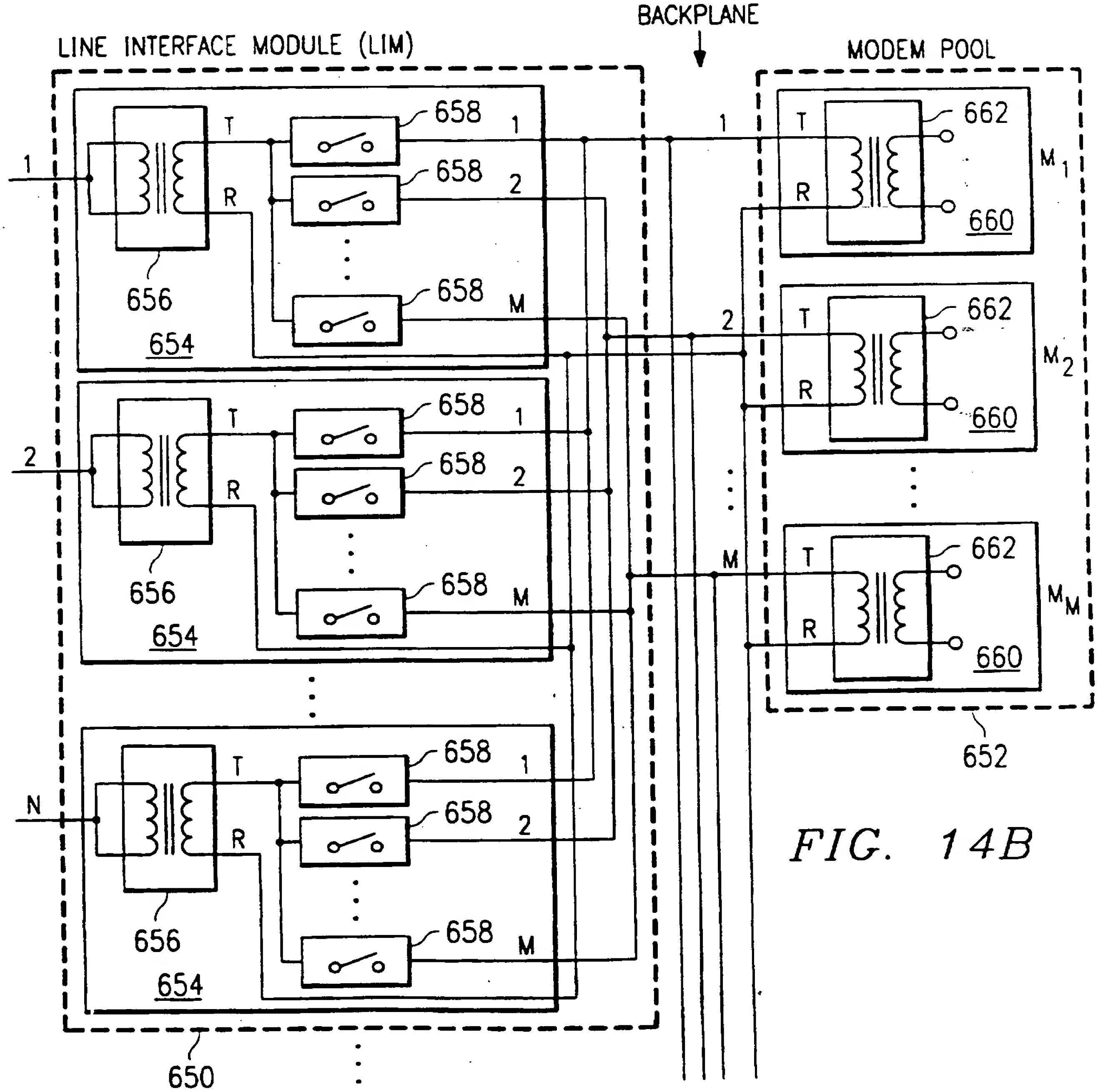


FIG. 14B

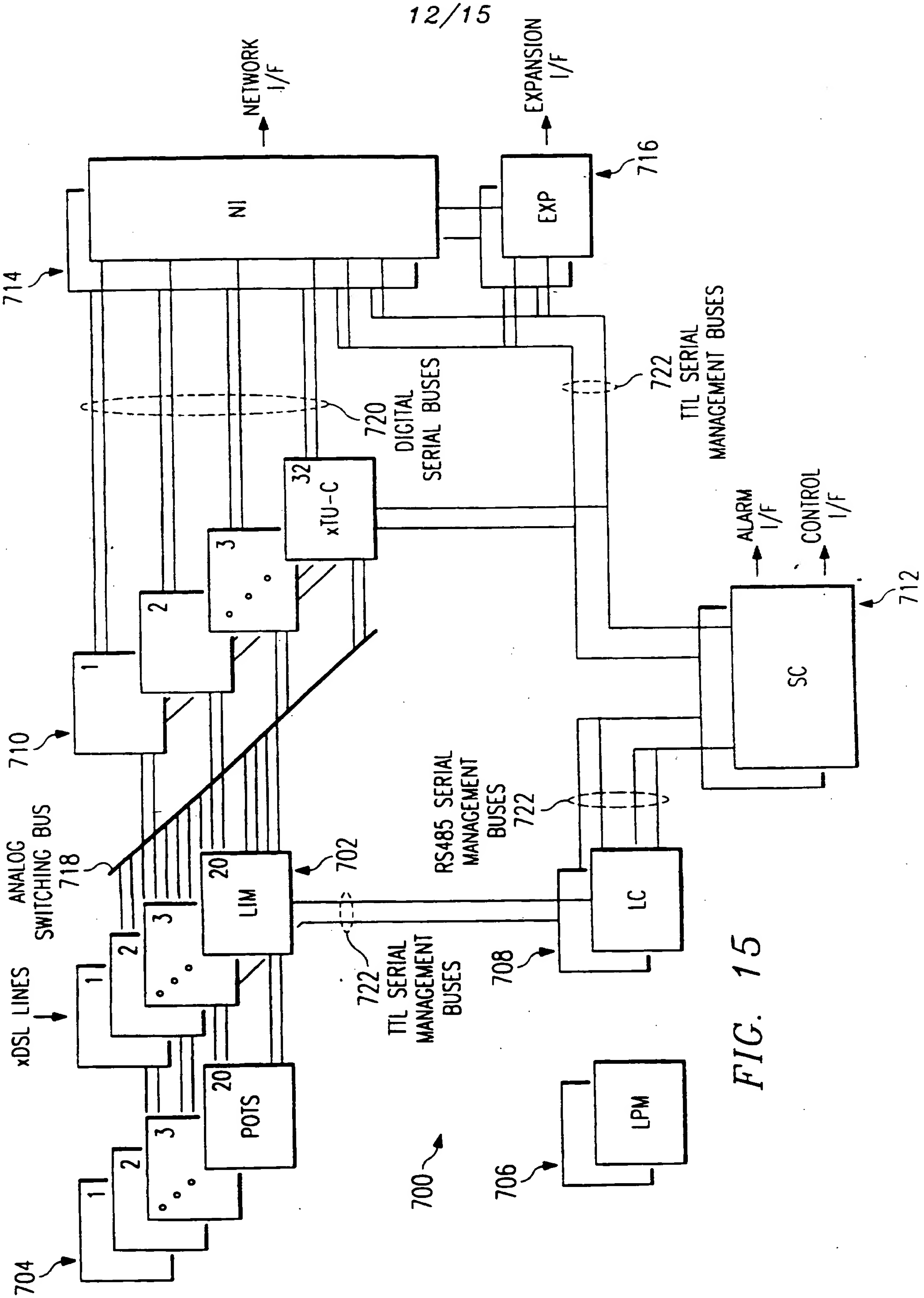

NETWORK I/F
EXPANSION I/F
NI
EXP
716
714
720
DIGITAL SERIAL BUSES
722
TTL SERIAL MANAGEMENT BUSES
32
xTU-C
ALARM I/F
CONTROL I/F
712
SC
1
2
3
710
ANALOG SWITCHING BUS
718
xDSL LINES
20
LIM
702
RS485 SERIAL MANAGEMENT BUSES
722
LC
708
722
TTL SERIAL MANAGEMENT BUSES
20
POTS
704
700
LPM
706

FIG. 15

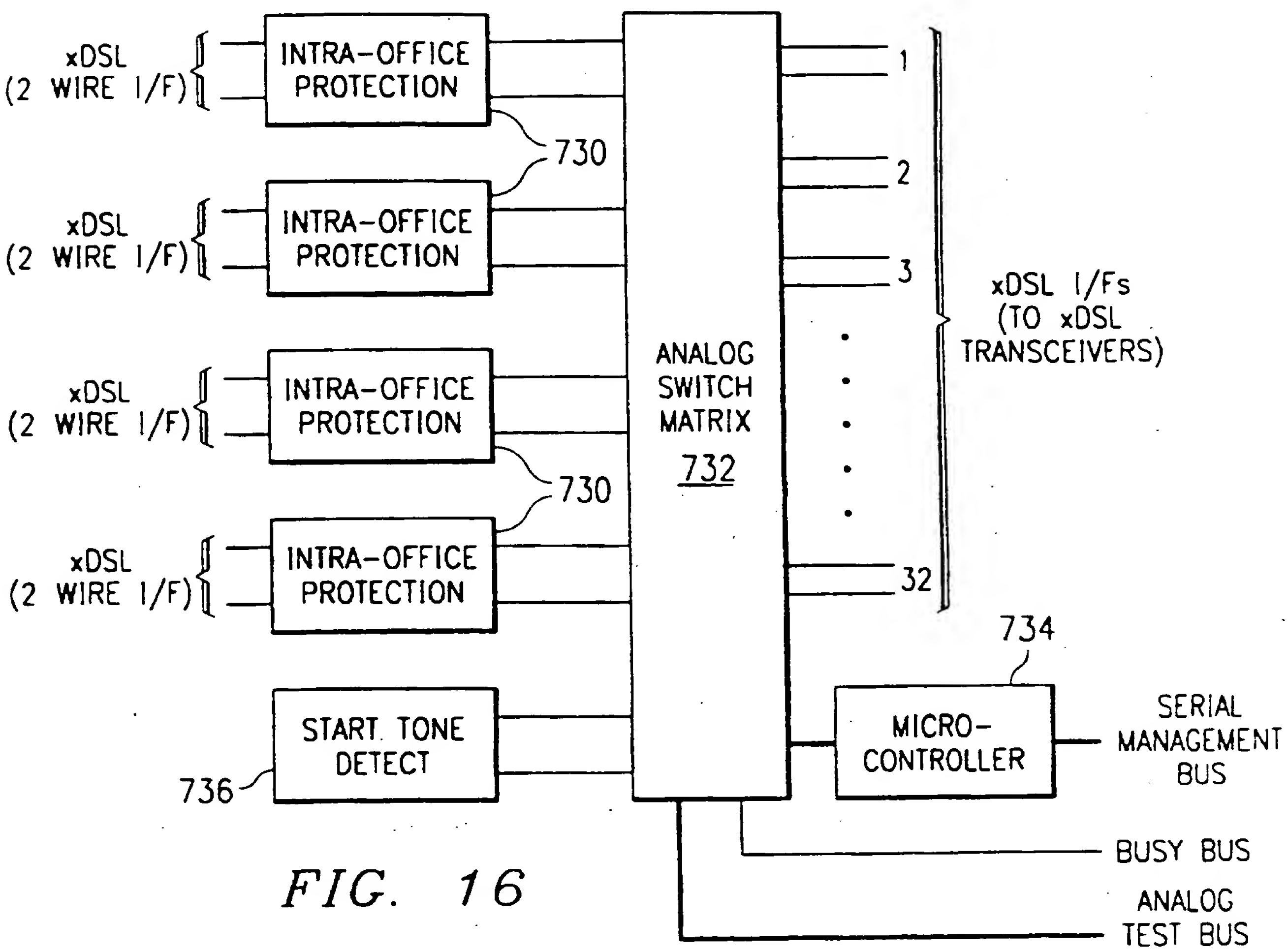
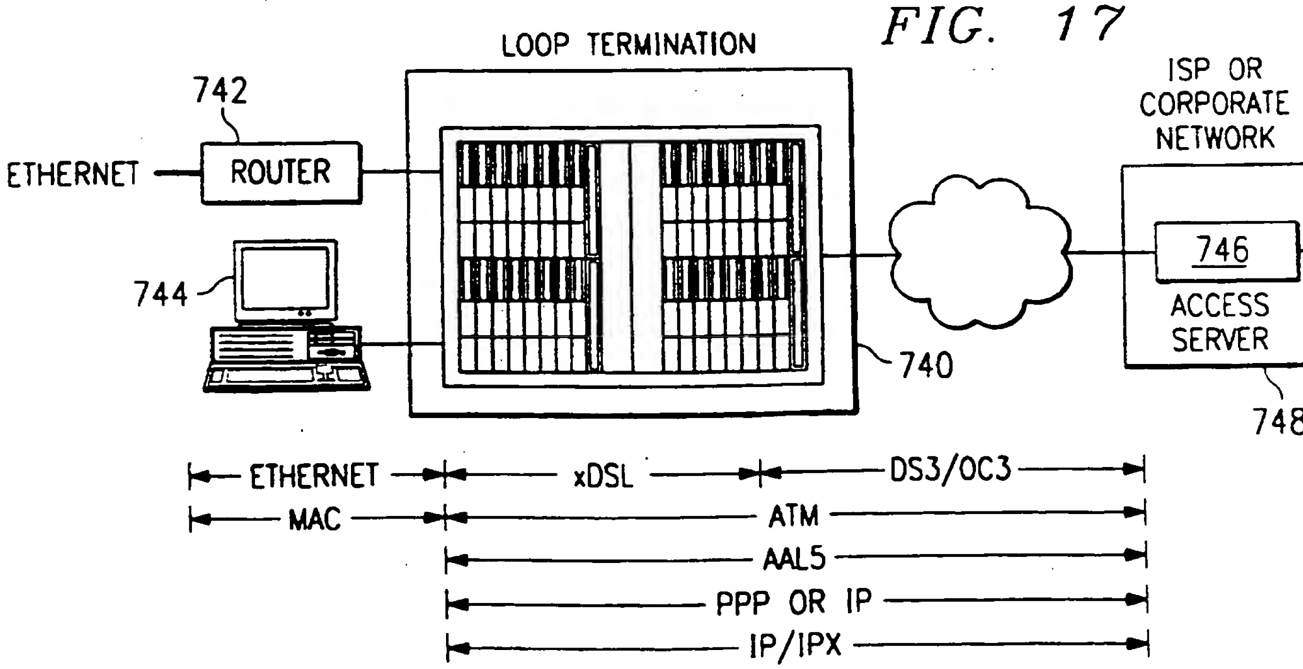

xDSL
(2 WIRE I/F)
INTRA-OFFICE PROTECTION
730
ANALOG SWITCH MATRIX
732
1
2
3
32
xDSL I/Fs
(TO xDSL TRANSCEIVERS)
734
MICRO-CONTROLLER
SERIAL MANAGEMENT BUS
START TONE DETECT
736
BUSY BUS
ANALOG TEST BUS

FIG. 16

FIG. 17


LOOP TERMINATION
742
ETHERNET
ROUTER
744
740
ISP OR CORPORATE NETWORK
746
ACCESS SERVER
748
ETHERNET
xDSL
DS3/OC3
MAC
ATM
AAL5
PPP OR IP
IP/IPX

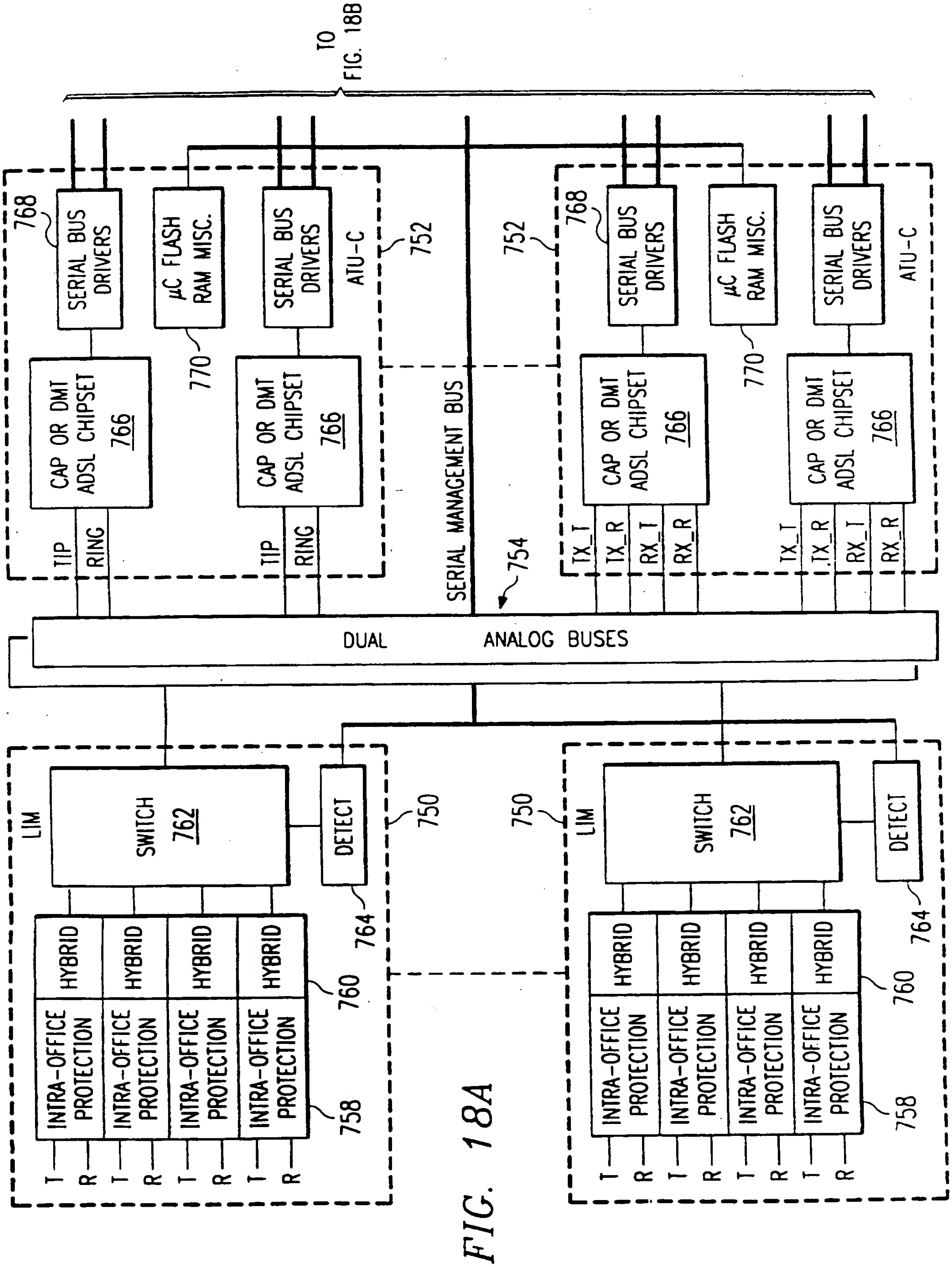

TO
FIG. 18B
768
SERIAL BUS
DRIVERS
μC FLASH
RAM MISC.
SERIAL BUS
DRIVERS
ATU-C
752
CAP OR DMT
ADSL CHIPSET
766
770
TIP
RING
SERIAL MANAGEMENT BUS
754
TX_T
TX_R
RX_T
RX_R
DUAL ANALOG BUSES
LIM
SWITCH
762
DETECT
750
764
HYBRID
760
INTRA-OFFICE
PROTECTION
758
T
R

FIG. 18A

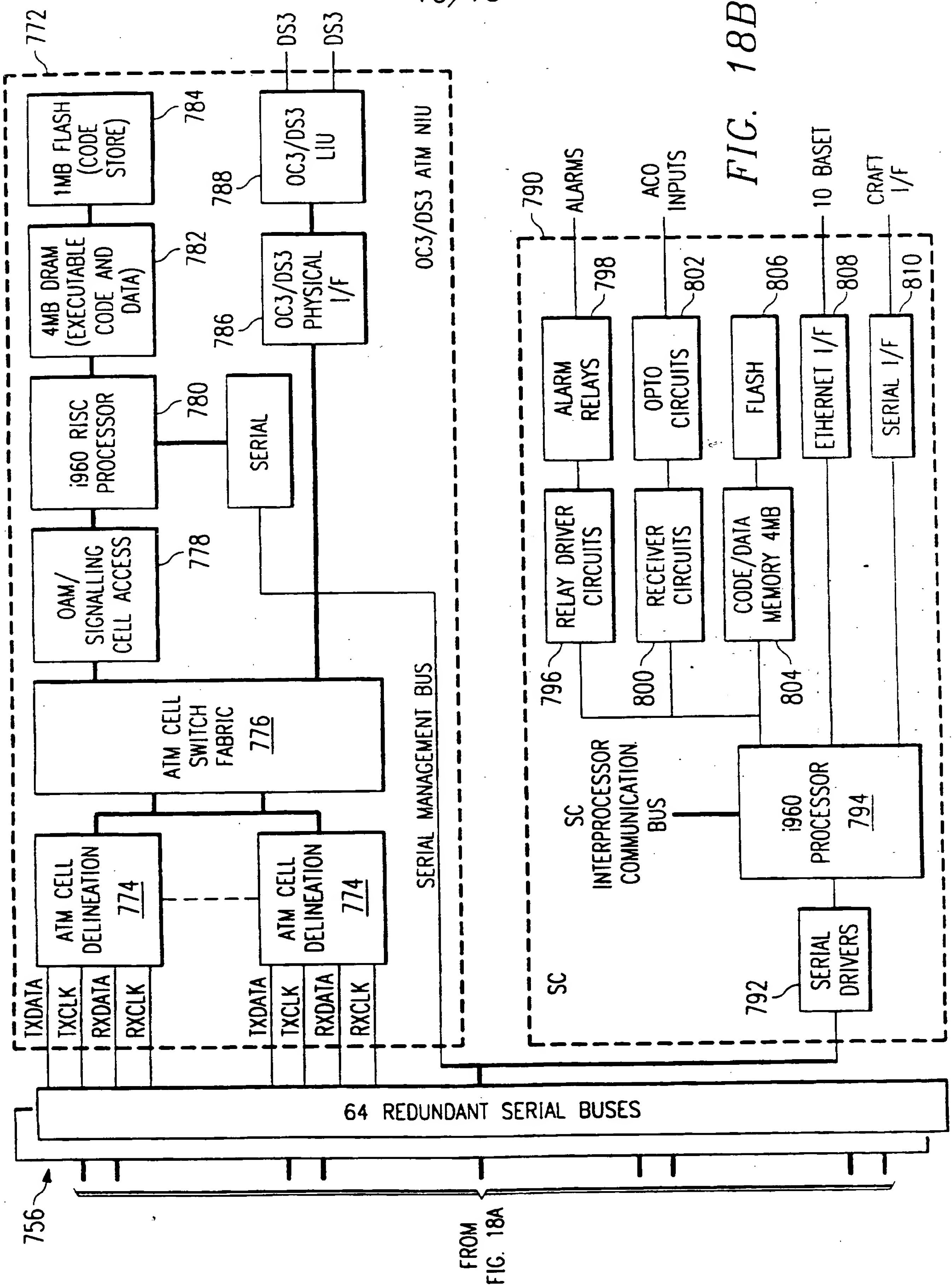


FIG. 18B

BNSDOCID: <WO 9737458A2 I >

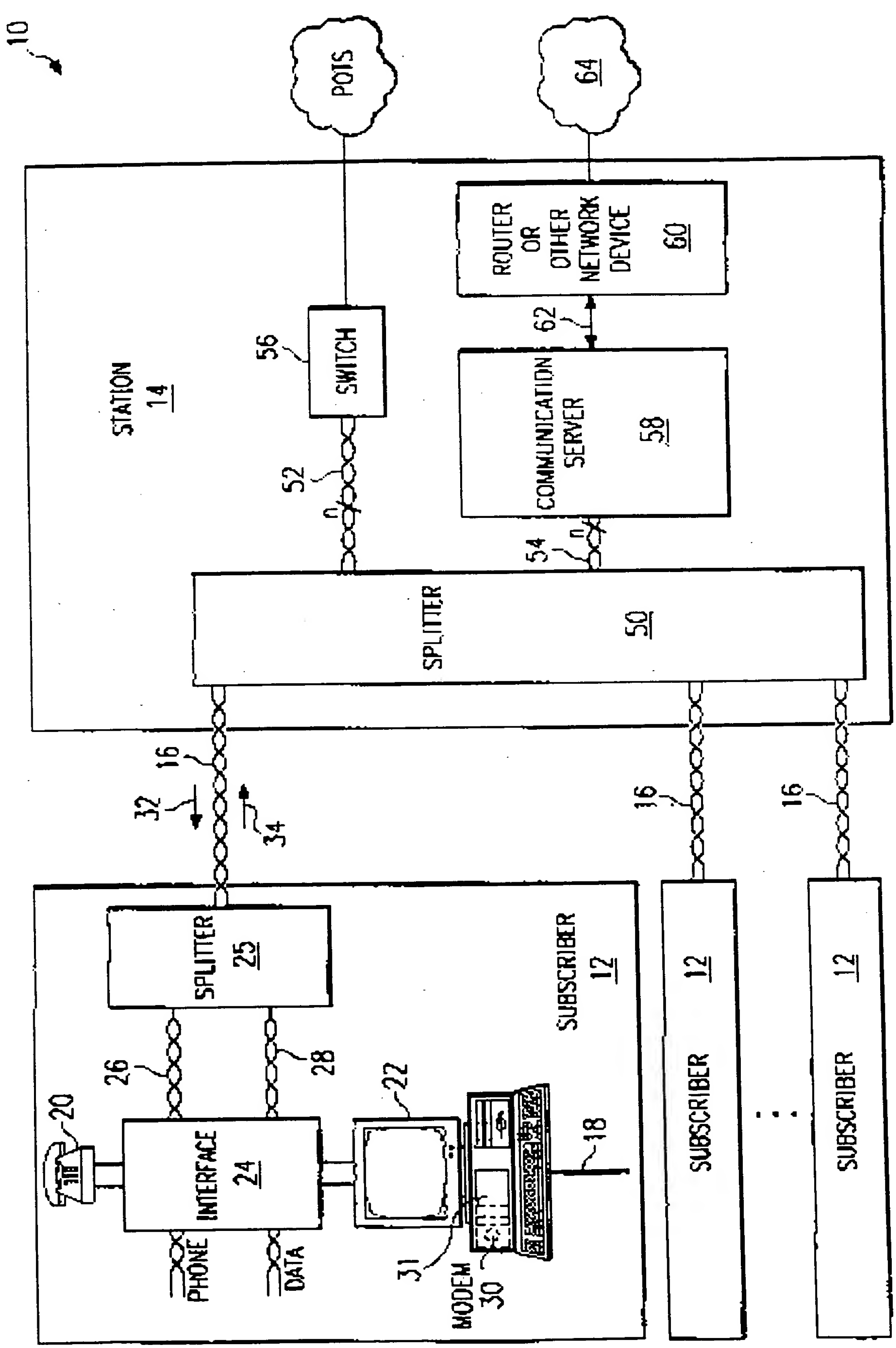

10
POTS
64
STATION
14
SWITCH
56
52
n
ROUTER
OR
OTHER
NETWORK
DEVICE
60
62
COMMUNICATION
SERVER
58
54
n
SPLITTER
50
16
32
34
16
16
SPLITTER
25
SUBSCRIBER
12
26
28
20
INTERFACE
24
22
18
PHONE
DATA
31
MODEM
30
SUBSCRIBER
12
SUBSCRIBER
12

FIG. 1

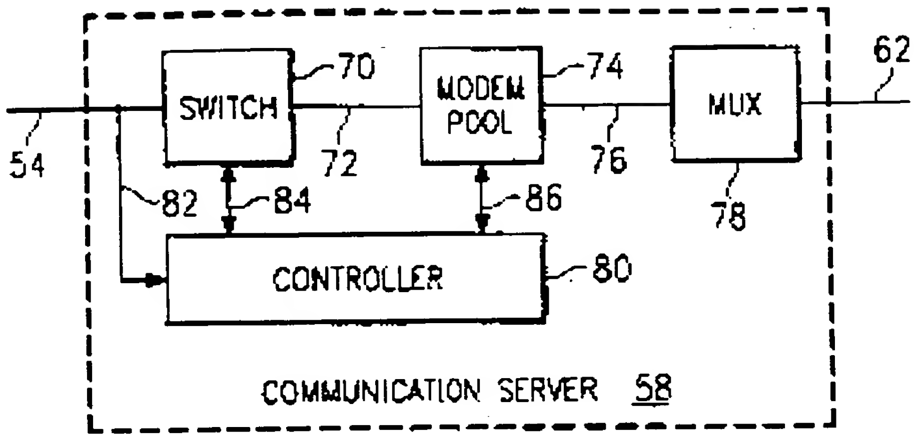

SWITCH
70
MODEM POOL
74
MUX
62
54
72
76
82
84
86
78
CONTROLLER
80
COMMUNICATION SERVER 58

FIG. 2

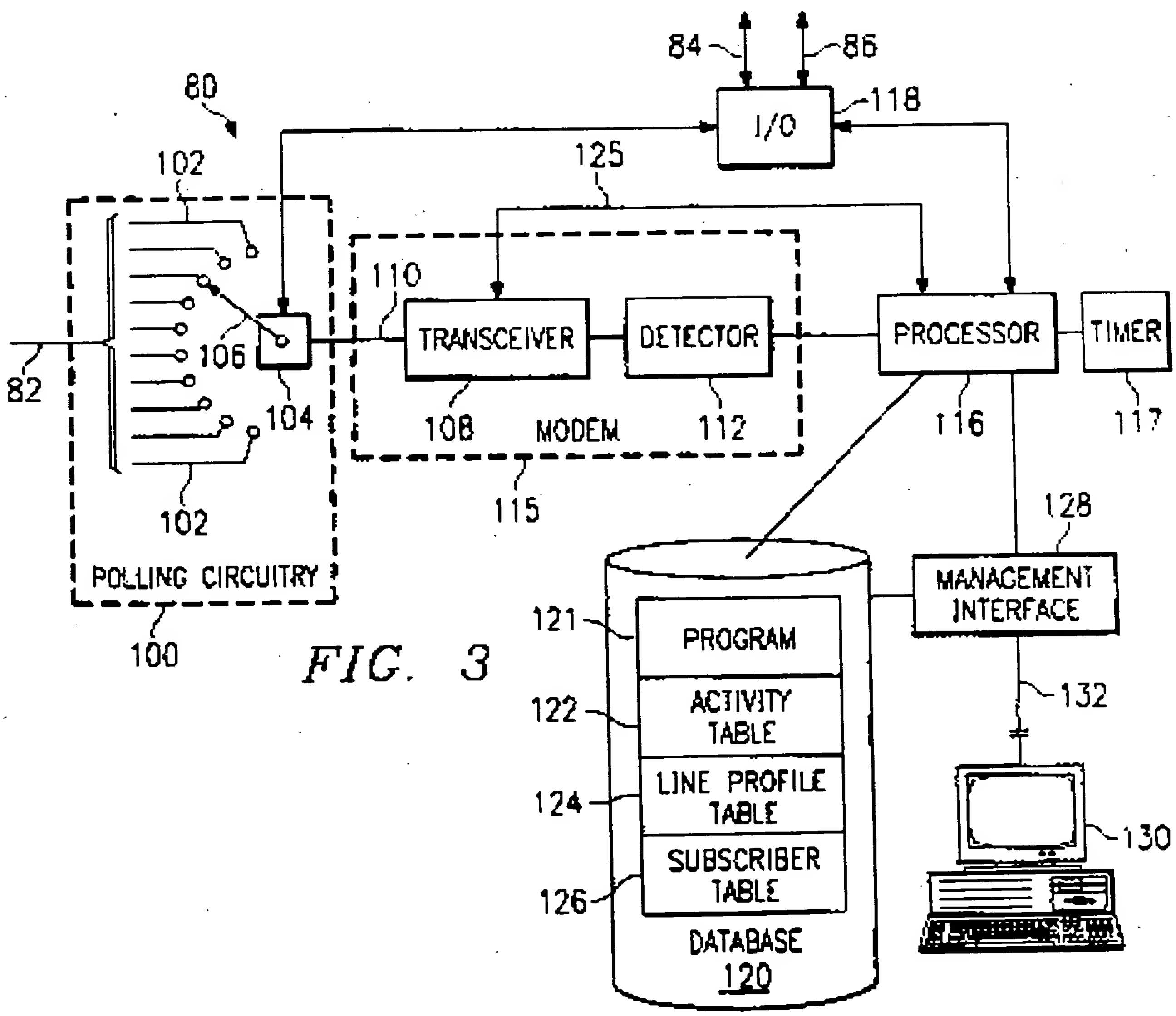

84
86
80
I/O
118
102
125
110
TRANSCEIVER
DETECTOR
PROCESSOR
TIMER
106
82
104
108
MODEM
112
116
117
102
115
128
POLLING CIRCUITRY
MANAGEMENT INTERFACE
100
121
PROGRAM
122
ACTIVITY TABLE
132
124
LINE PROFILE TABLE
130
126
SUBSCRIBER TABLE
DATABASE
120

FIG. 3

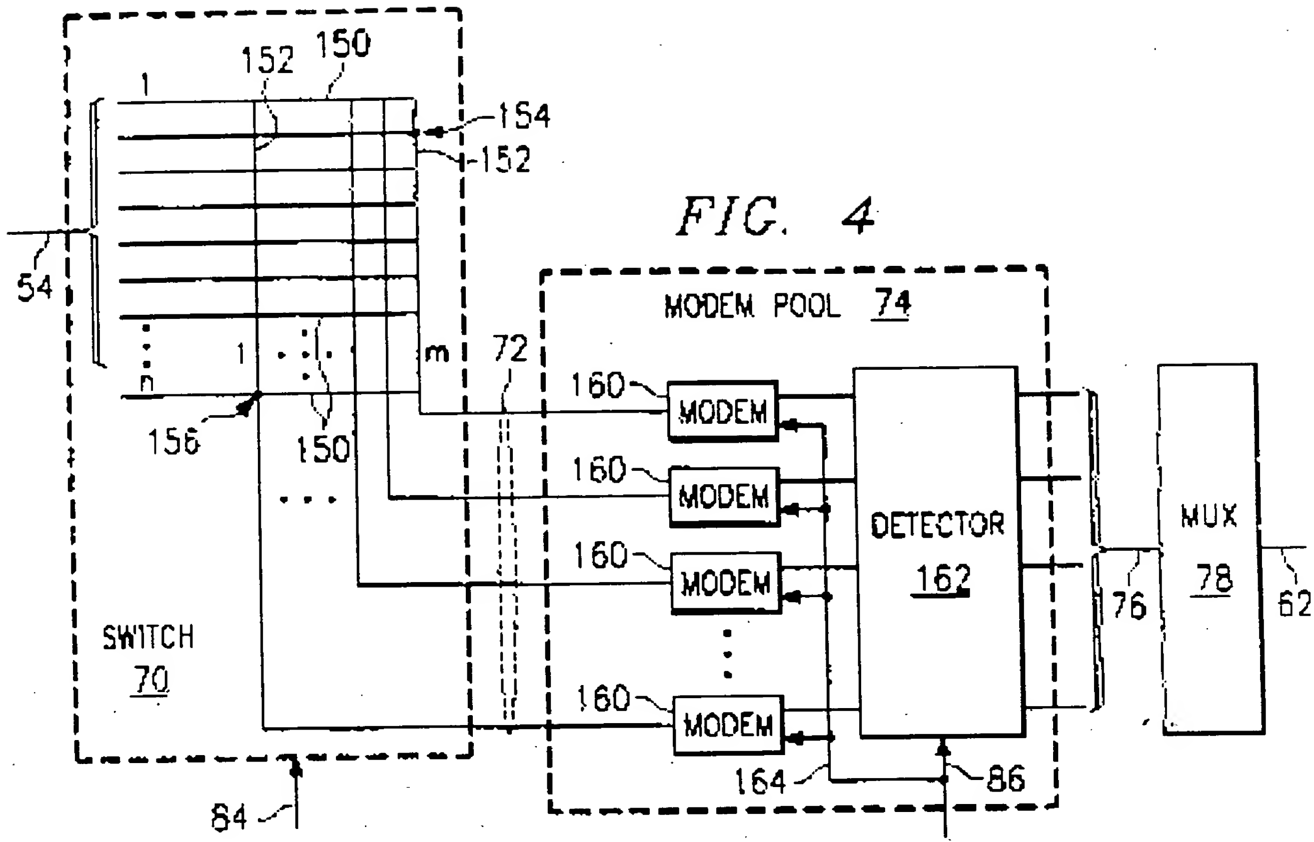


FIG. 4

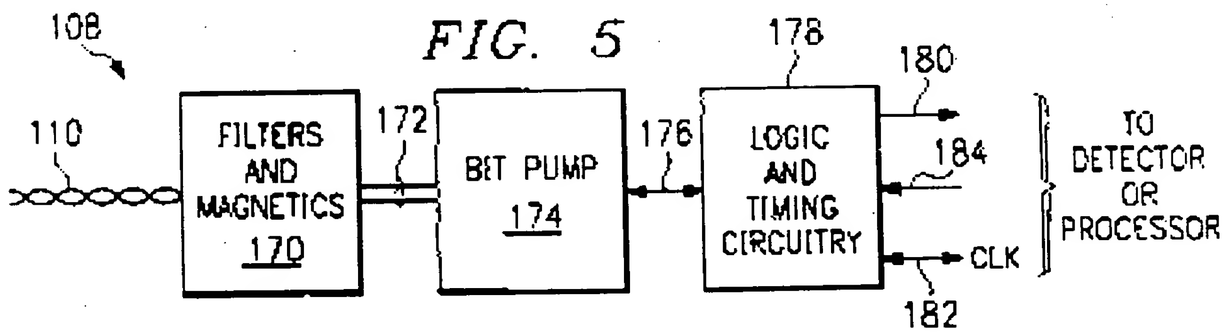


FIG. 5

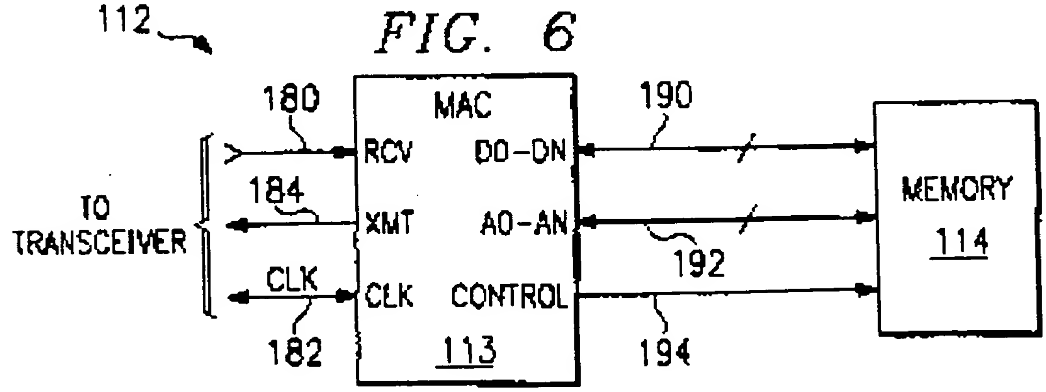


FIG. 6

122

DATA LINE (200)	STATUS (202)	TIMEOUT (204)	MODEM (206)
D1 (208)	I	–	–
D2 (210)	I/D	–	M1
D3	I	–	–
D4 (212)	A	T	M3
D5	I	–	–
D6	I	–	–
D7	A/D	–	M2
D8	A	–	M4
D9	I	–	–
D10	I	–	–

FIG. 7

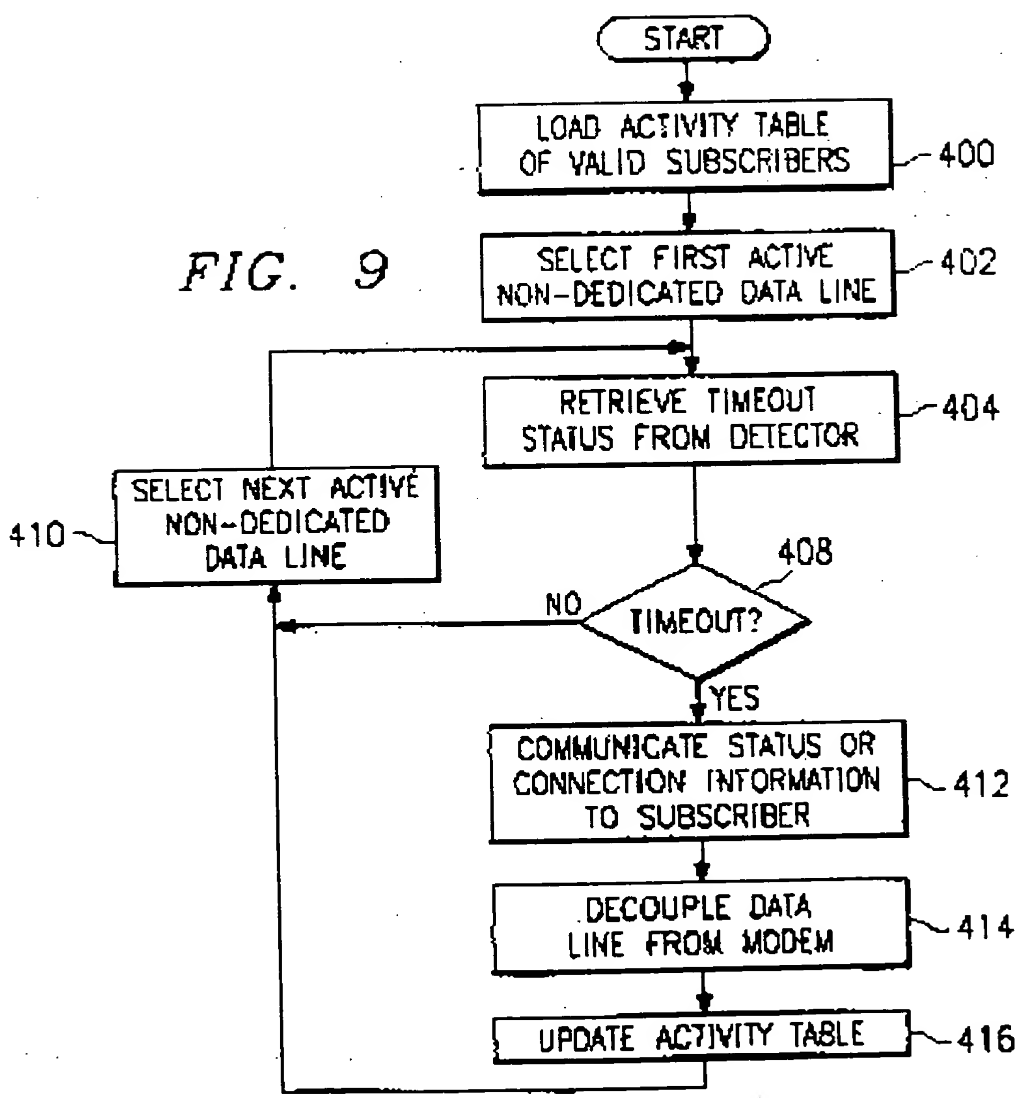


FIG. 9

FIG. 8

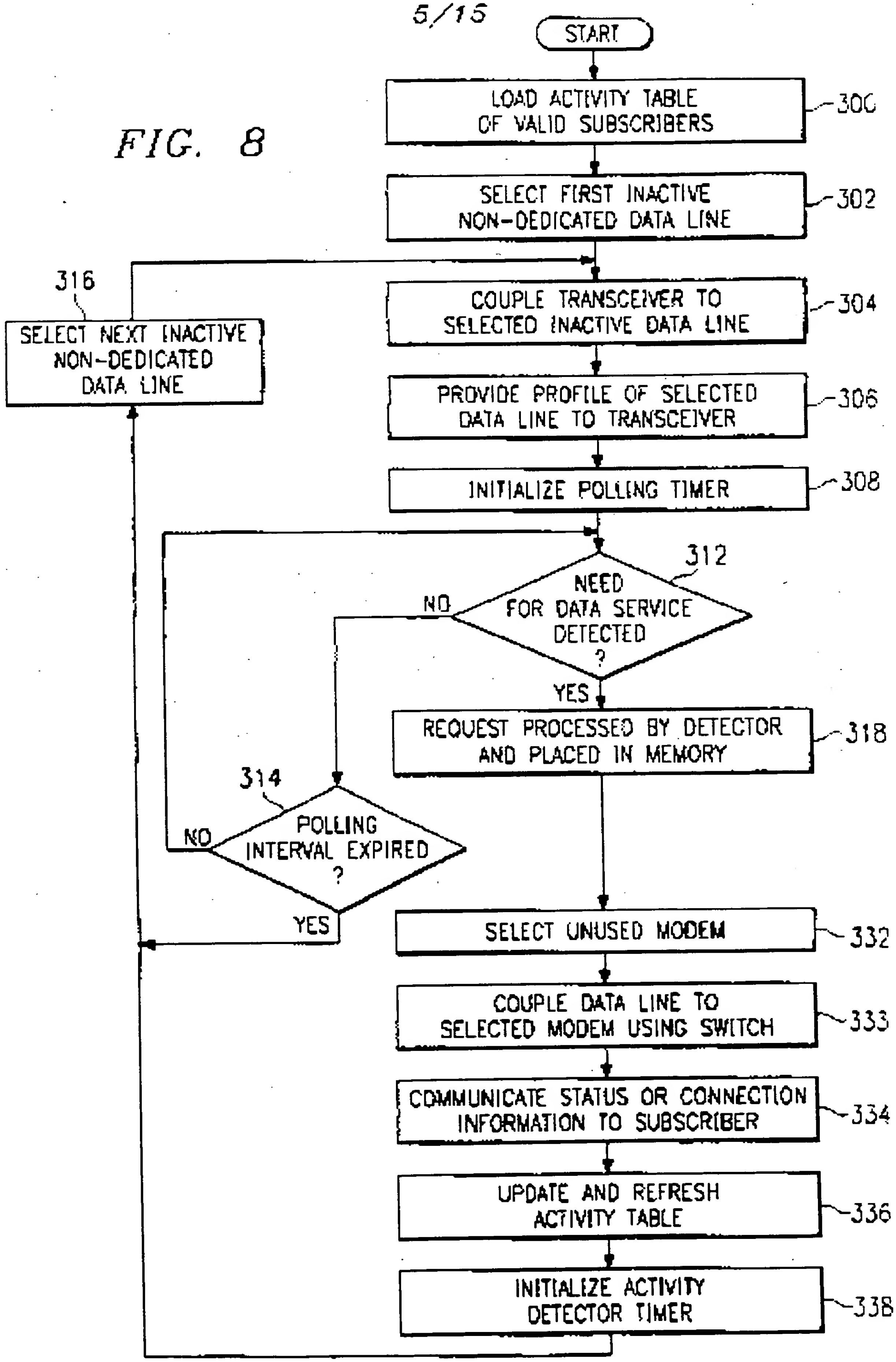

START
LOAD ACTIVITY TABLE OF VALID SUBSCRIBERS
300
SELECT FIRST INACTIVE NON-DEDICATED DATA LINE
302
316
SELECT NEXT INACTIVE NON-DEDICATED DATA LINE
COUPLE TRANSCEIVER TO SELECTED INACTIVE DATA LINE
304
PROVIDE PROFILE OF SELECTED DATA LINE TO TRANSCEIVER
306
INITIALIZE POLLING TIMER
308
312
NEED FOR DATA SERVICE DETECTED ?
NO
YES
REQUEST PROCESSED BY DETECTOR AND PLACED IN MEMORY
318
314
POLLING INTERVAL EXPIRED ?
NO
YES
SELECT UNUSED MODEM
332
COUPLE DATA LINE TO SELECTED MODEM USING SWITCH
333
COMMUNICATE STATUS OR CONNECTION INFORMATION TO SUBSCRIBER
334
UPDATE AND REFRESH ACTIVITY TABLE
336
INITIALIZE ACTIVITY DETECTOR TIMER
338

FIG. 10A

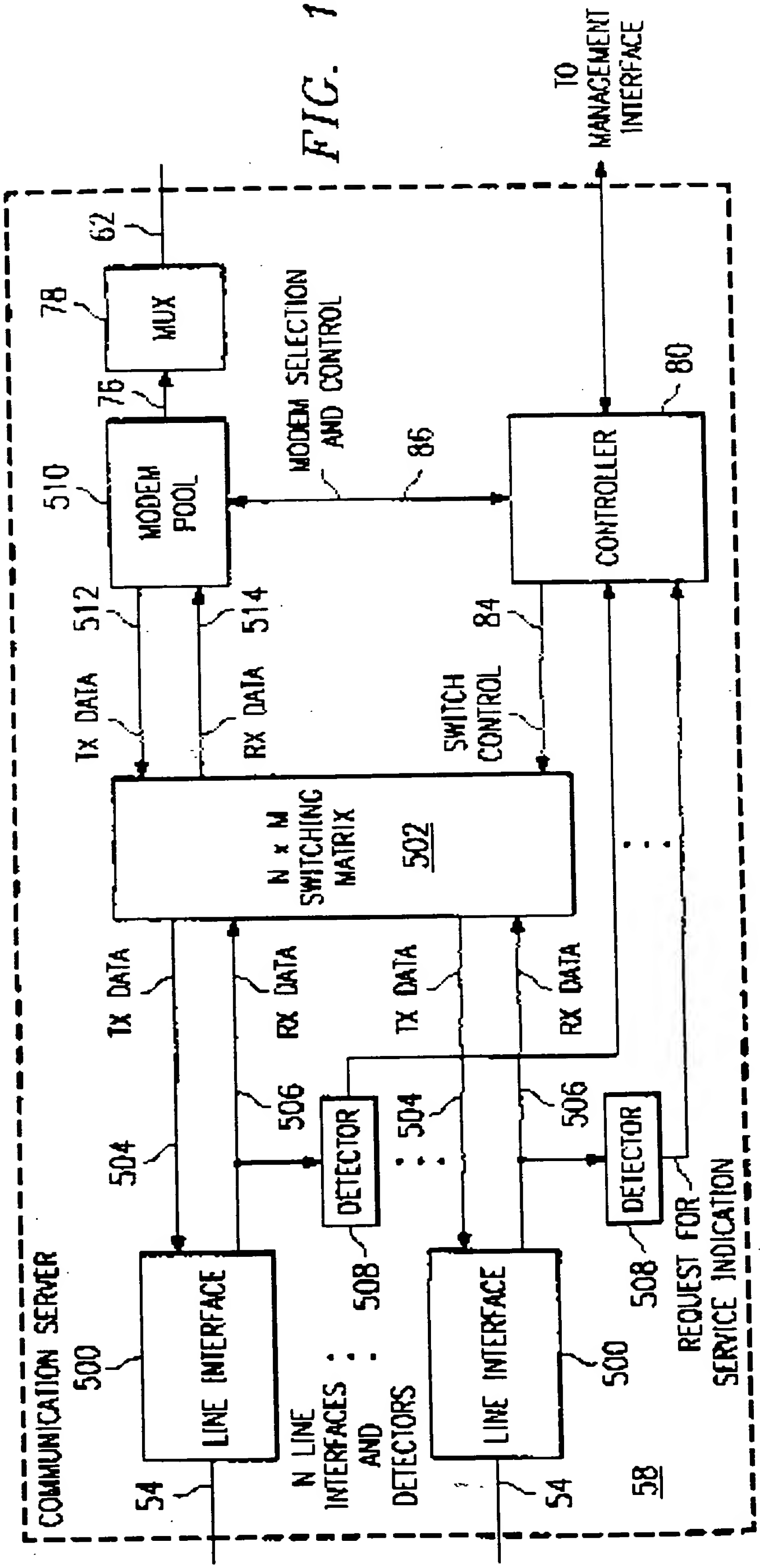
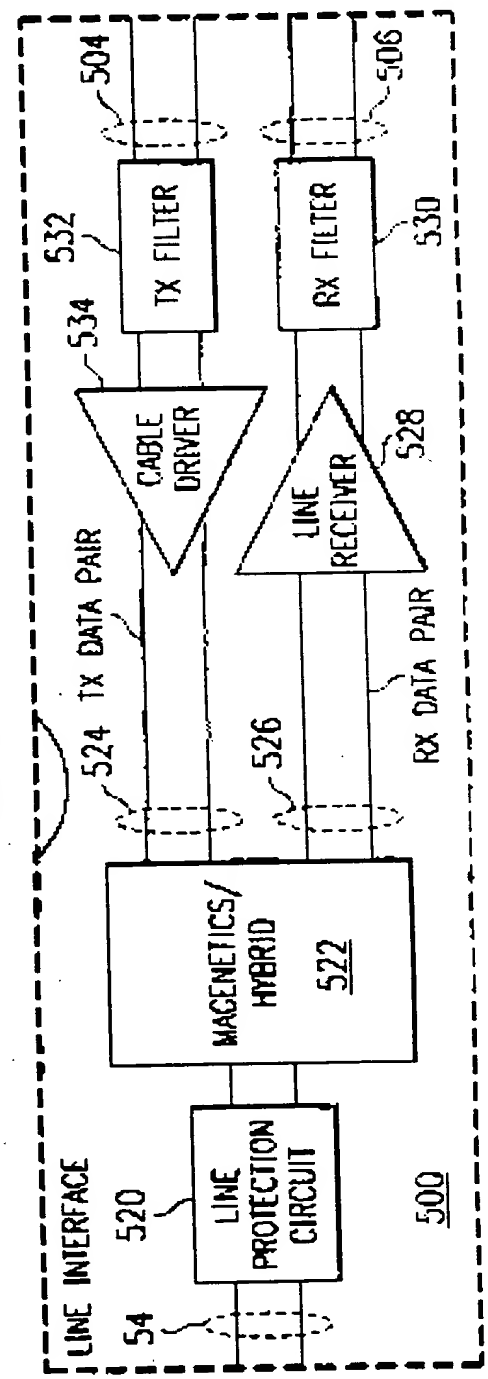


FIG. 10B



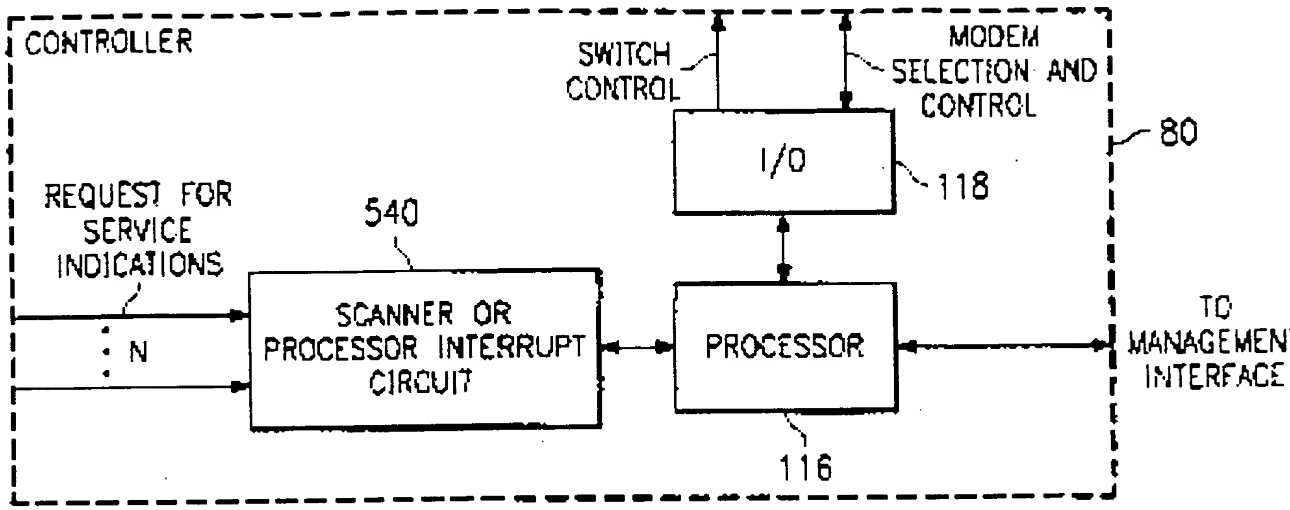


FIG. 10C

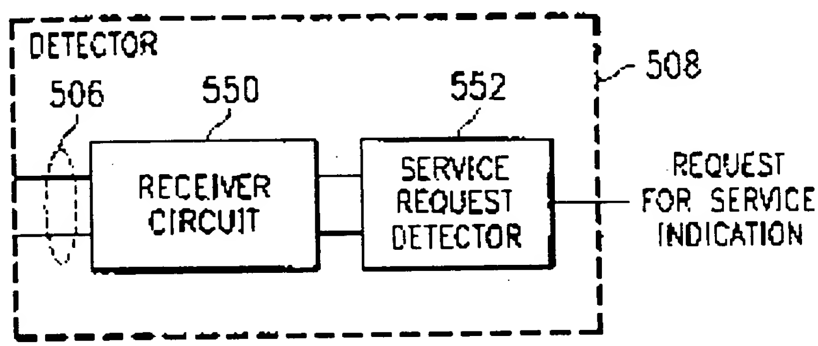


FIG. 10D

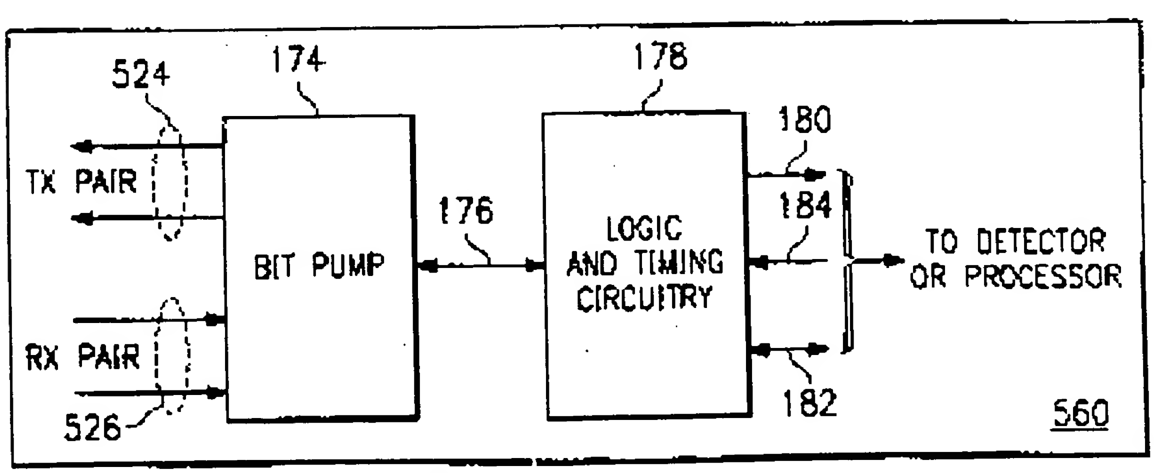


FIG. 10E

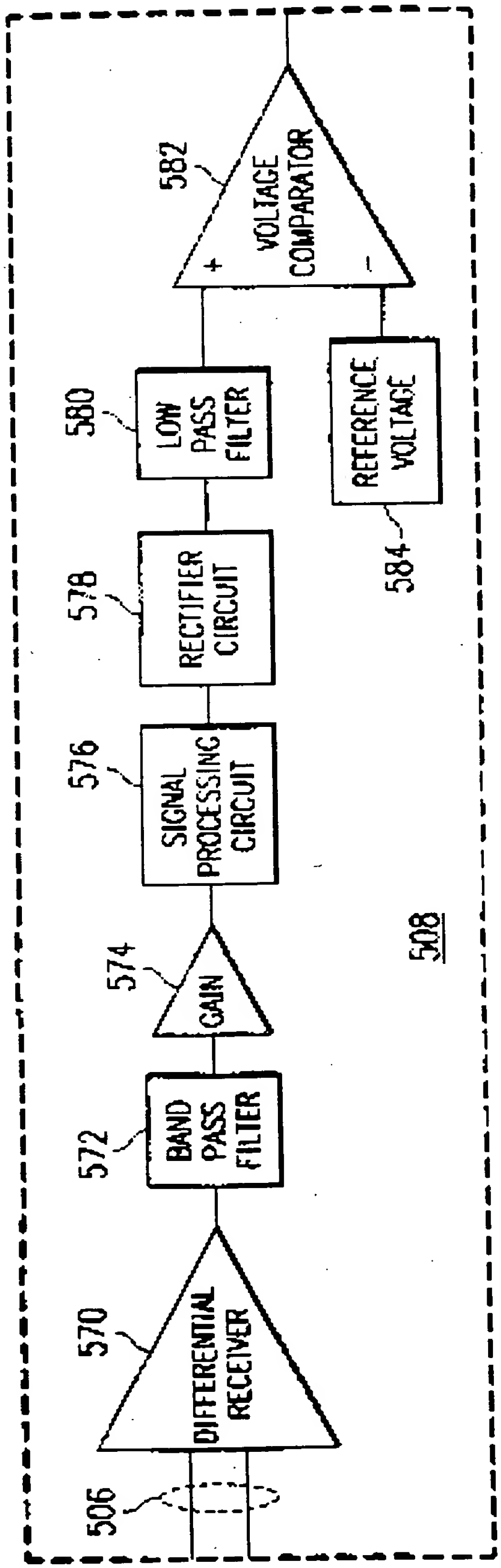


FIG. 11A

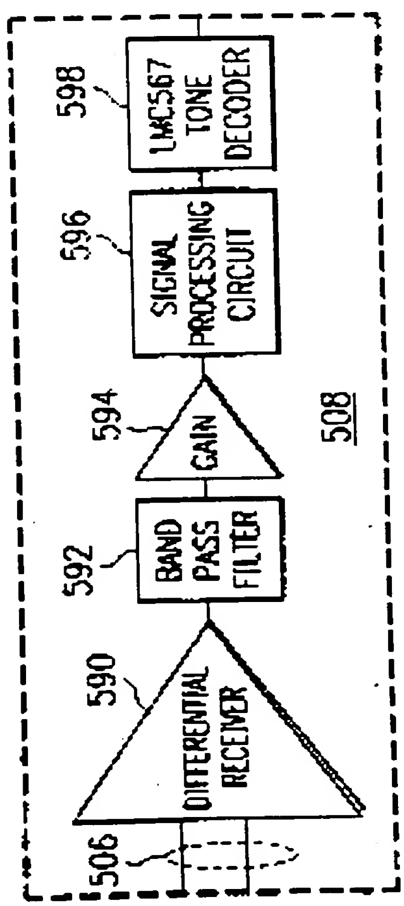


FIG. 11B

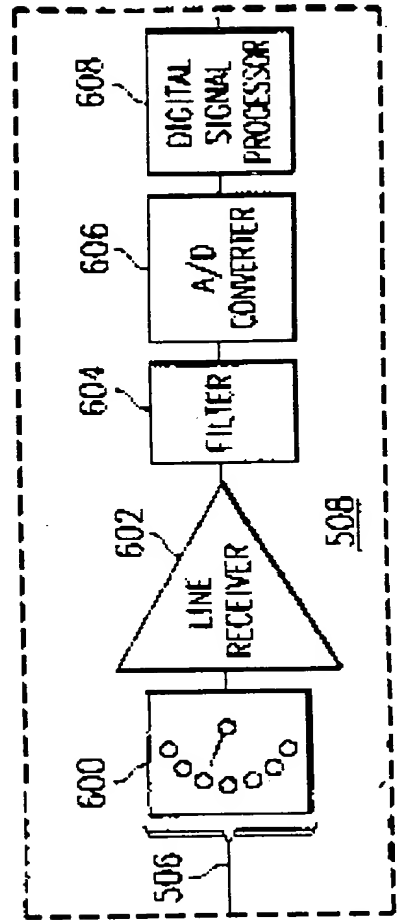


FIG. 11C

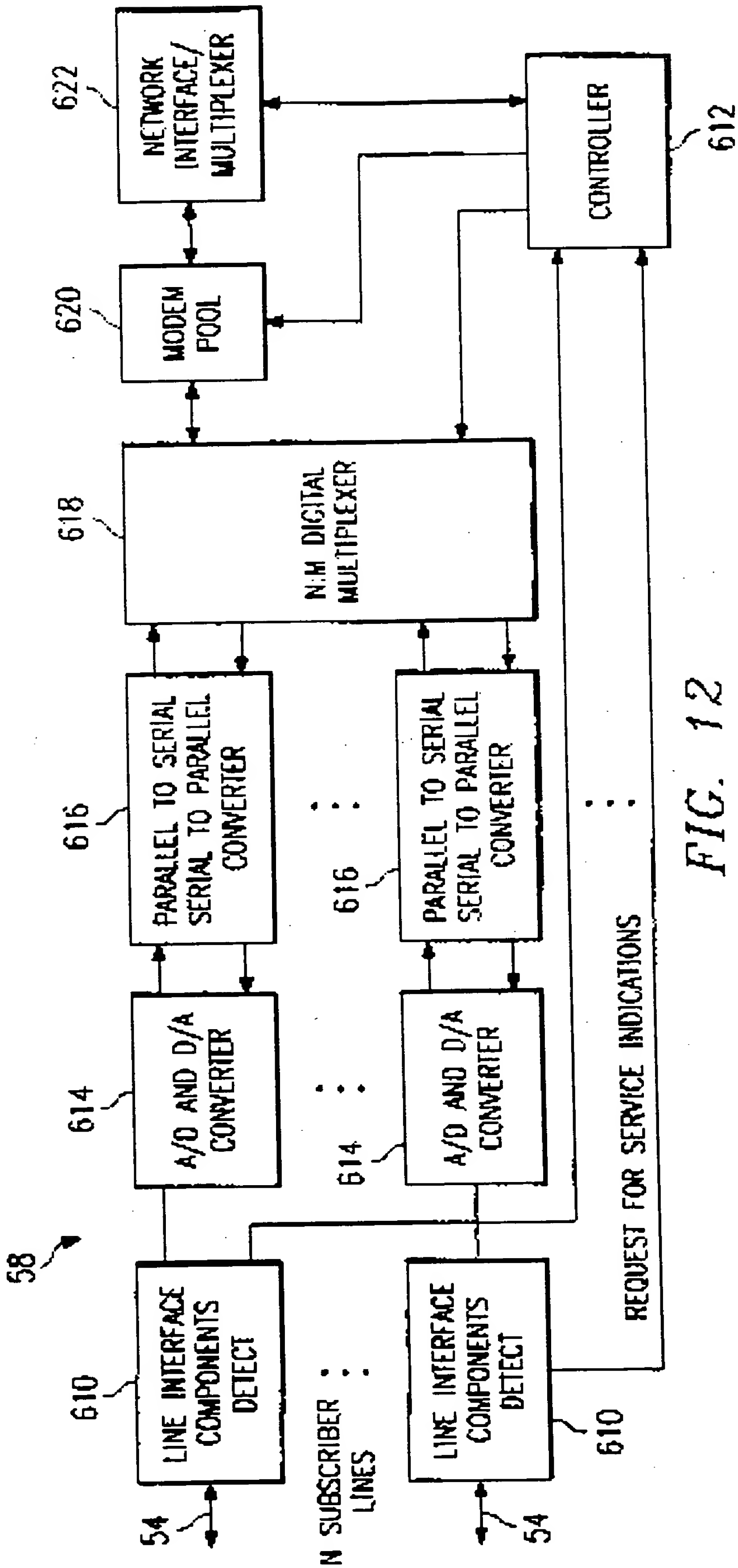


FIG. 12

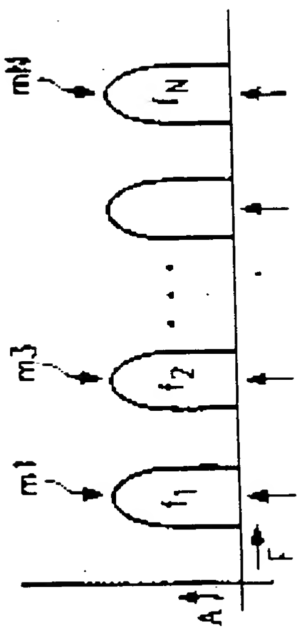


FIG. 13B

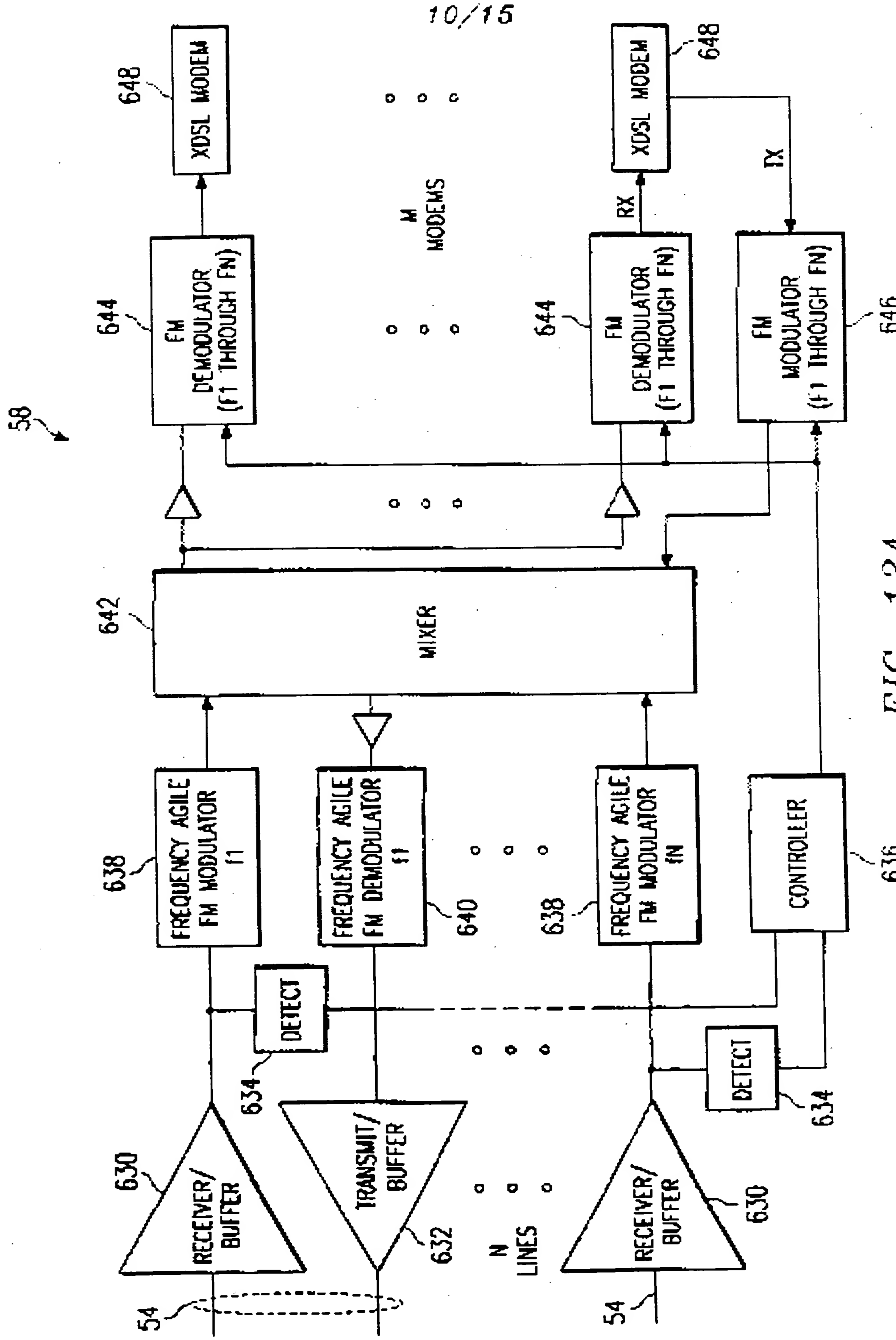

58
648
XDSL MODEM
648
XDSL MODEM
M
MODEMS
RX
TX
644
FM
DEMODULATOR
(F1 THROUGH FN)
644
FM
DEMODULATOR
(F1 THROUGH FN)
646
FM
MODULATOR
(F1 THROUGH FN)
642
MIXER
638
FREQUENCY AGILE
FM MODULATOR
f1
640
FREQUENCY AGILE
FM DEMODULATOR
f1
638
FREQUENCY AGILE
FM MODULATOR
fN
636
CONTROLLER
634
DETECT
634
DETECT
630
RECEIVER/
BUFFER
632
TRANSMIT/
BUFFER
N
LINES
630
RECEIVER/
BUFFER
54
54

FIG. 13A

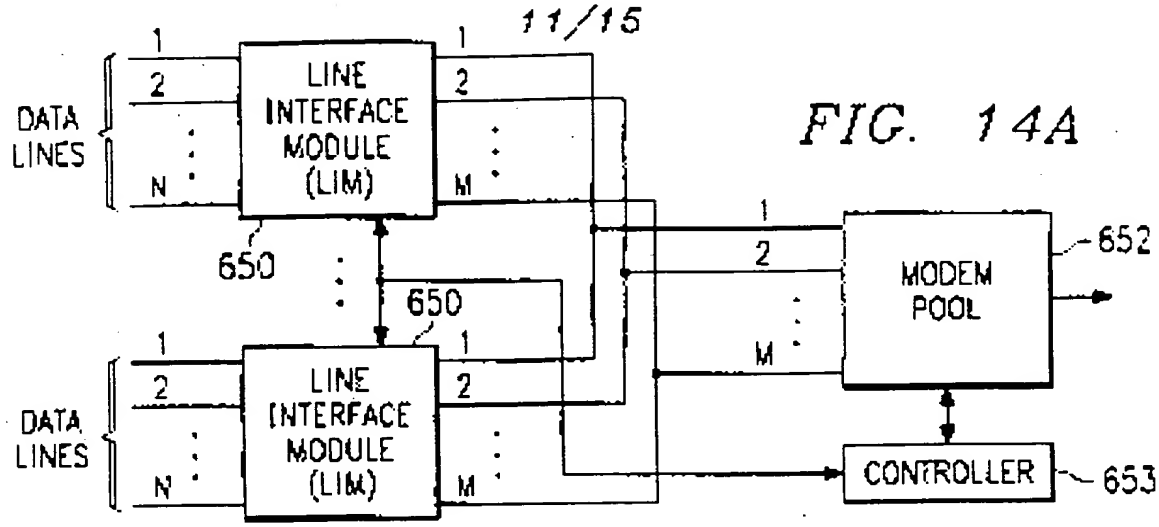


FIG. 14A

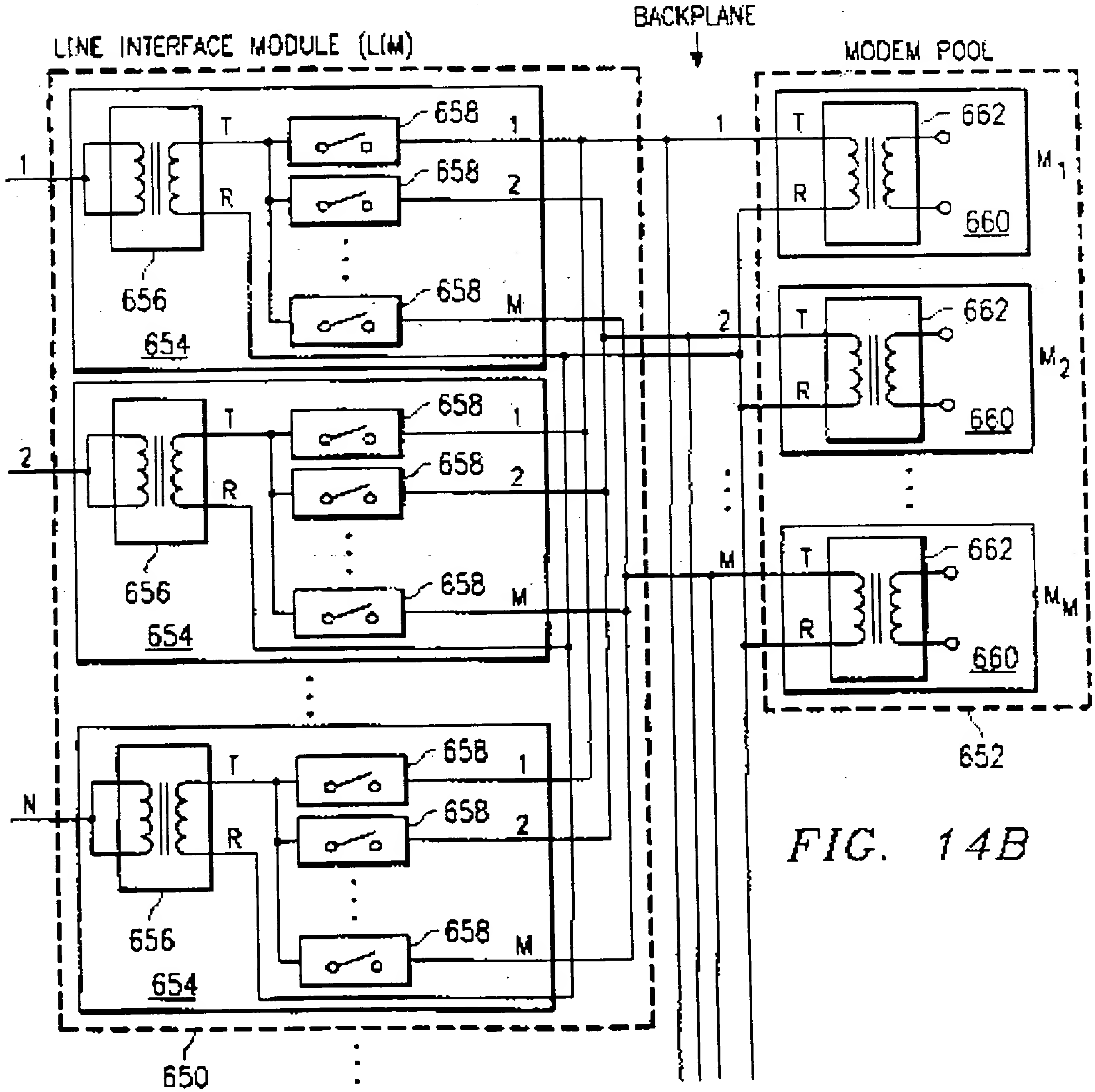


FIG. 14B

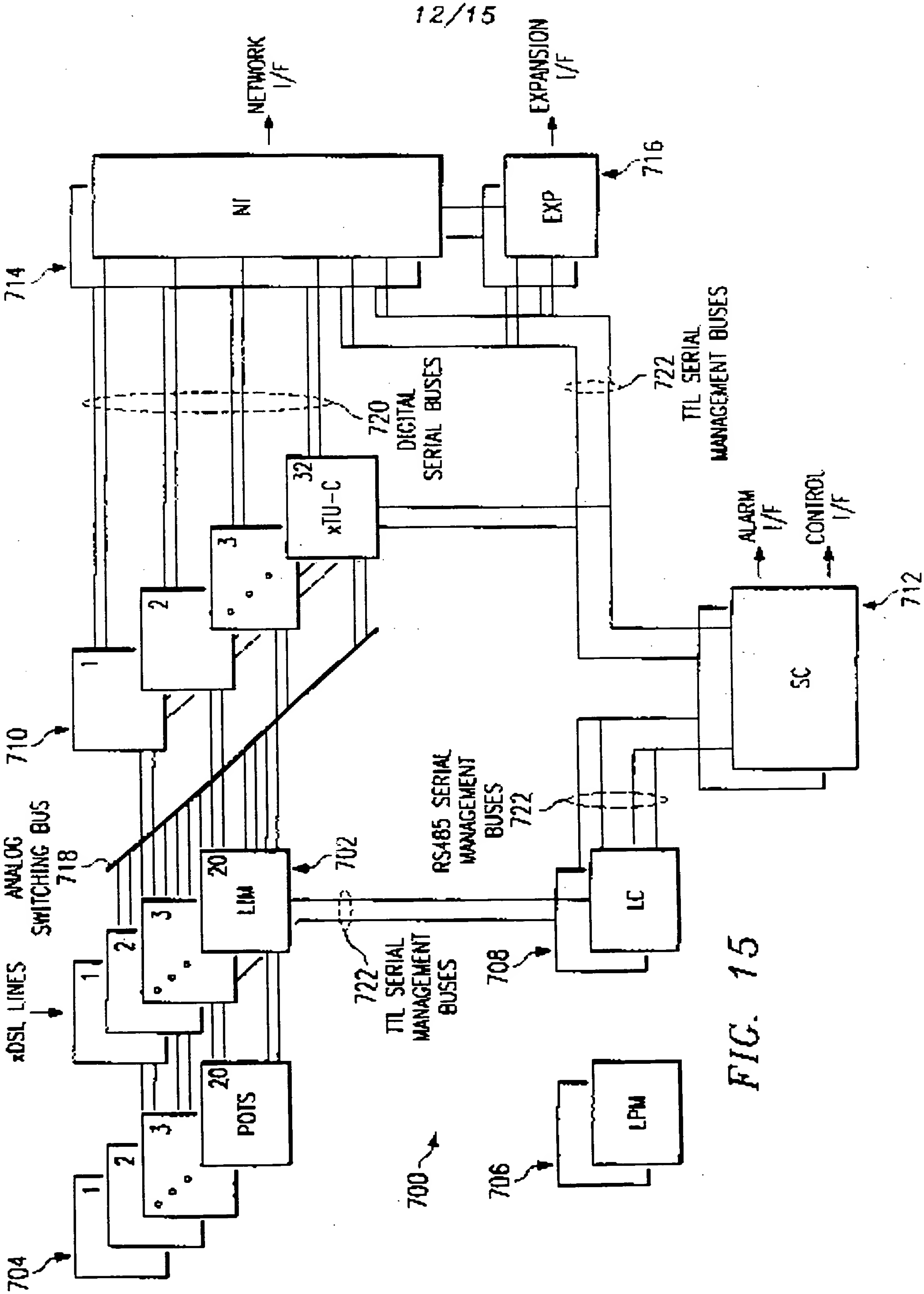

NETWORK I/F
EXPANSION I/F
NI
EXP
714
716
720
DIGITAL SERIAL BUSES
722
TTL SERIAL MANAGEMENT BUSES
32
xTU-C
1
2
3
710
ALARM I/F
CONTROL I/F
712
SC
ANALOG SWITCHING BUS 718
RS485 SERIAL MANAGEMENT BUSES 722
20
LIM
702
LC
708
xDSL LINES
722 TTL SERIAL MANAGEMENT BUSES
20
POTS
700
706
LPM
704

FIG. 15

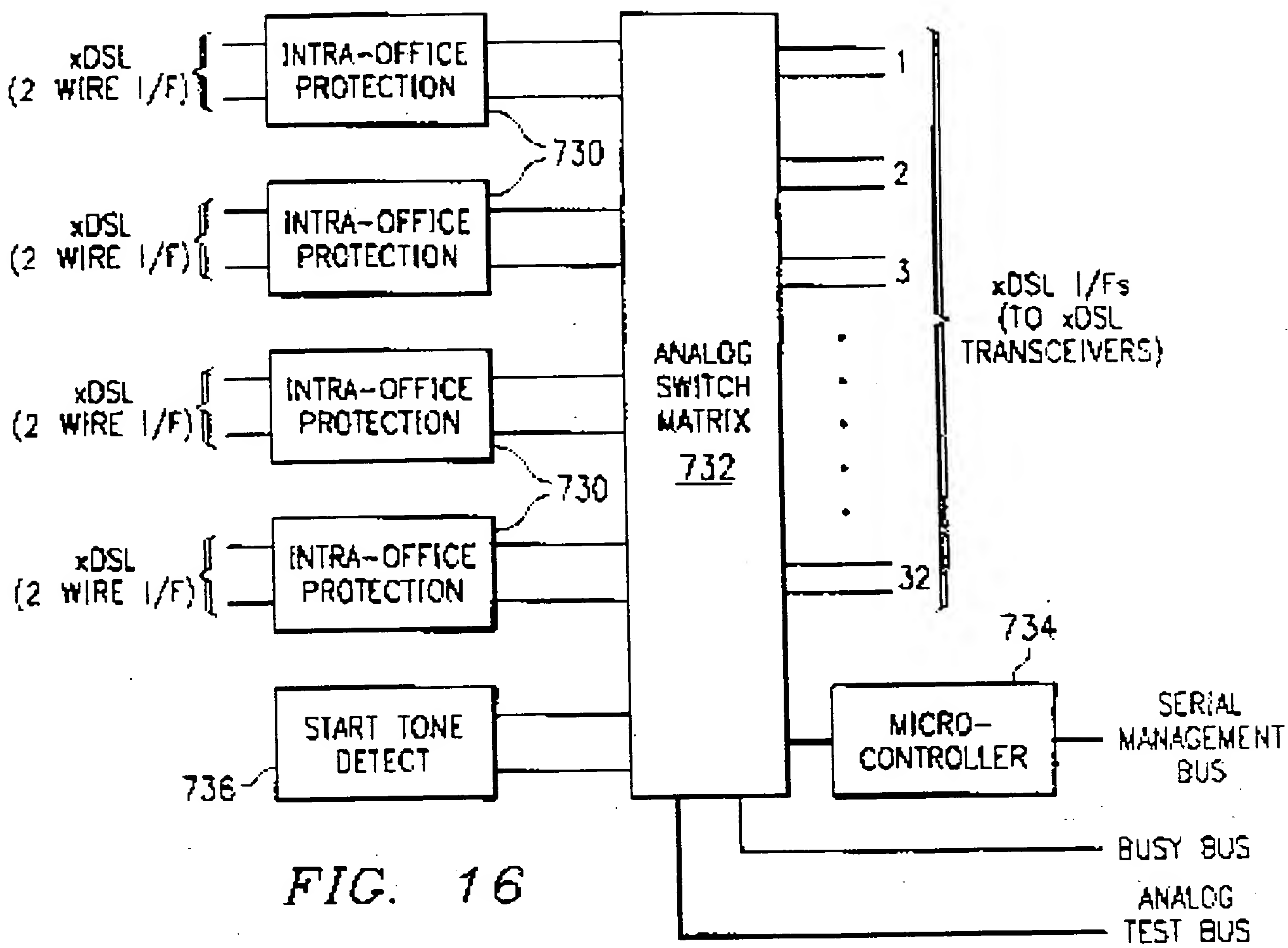
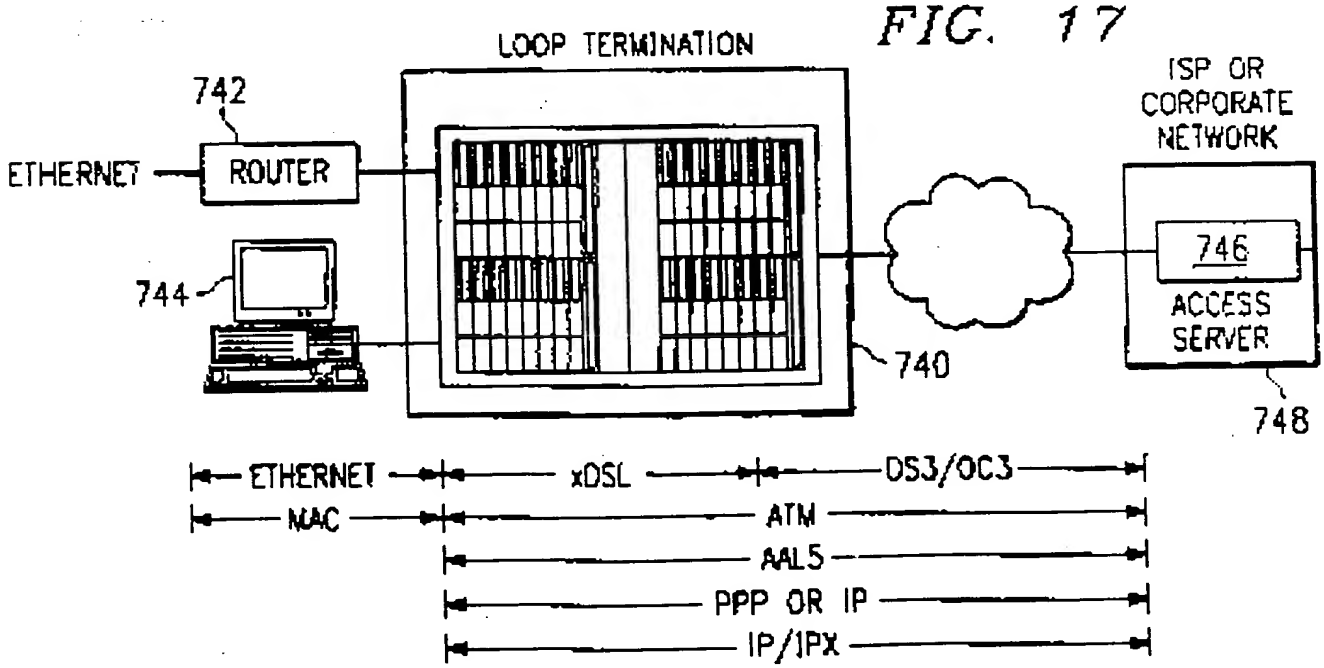

xDSL
(2 WIRE I/F)
INTRA-OFFICE PROTECTION
730
xDSL
(2 WIRE I/F)
INTRA-OFFICE PROTECTION
xDSL
(2 WIRE I/F)
INTRA-OFFICE PROTECTION
730
xDSL
(2 WIRE I/F)
INTRA-OFFICE PROTECTION
ANALOG SWITCH MATRIX
732
1
2
3
32
xDSL I/Fs
(TO xDSL TRANSCEIVERS)
734
START TONE DETECT
736
MICRO-CONTROLLER
SERIAL MANAGEMENT BUS
BUSY BUS
ANALOG TEST BUS

FIG. 16

FIG. 17


LOOP TERMINATION
742
ETHERNET
ROUTER
744
740
ISP OR CORPORATE NETWORK
746
ACCESS SERVER
748
ETHERNET
xDSL
DS3/OC3
MAC
ATM
AAL5
PPP OR IP
IP/IPX

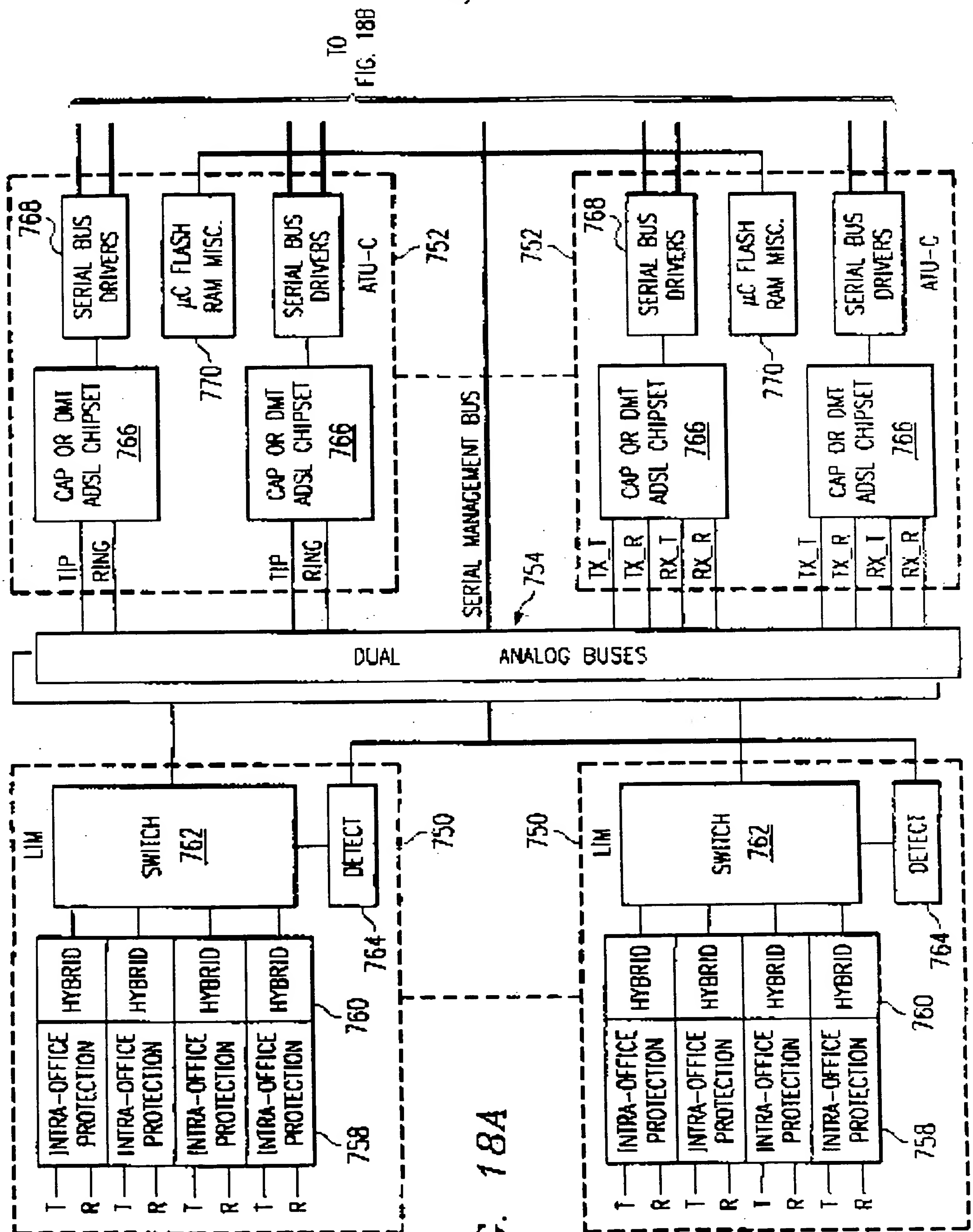

TO FIG. 18B
768
SERIAL BUS DRIVERS
μC FLASH RAM MISC.
770
ATU-C
752
CAP OR DMT ADSL CHIPSET 766
TIP
RING
TX_T
TX_R
RX_T
RX_R
SERIAL MANAGEMENT BUS
754
DUAL ANALOG BUSES
LIM
SWITCH 762
DETECT
764
750
HYBRID
760
INTRA-OFFICE PROTECTION
758
T
R

FIG. 18A

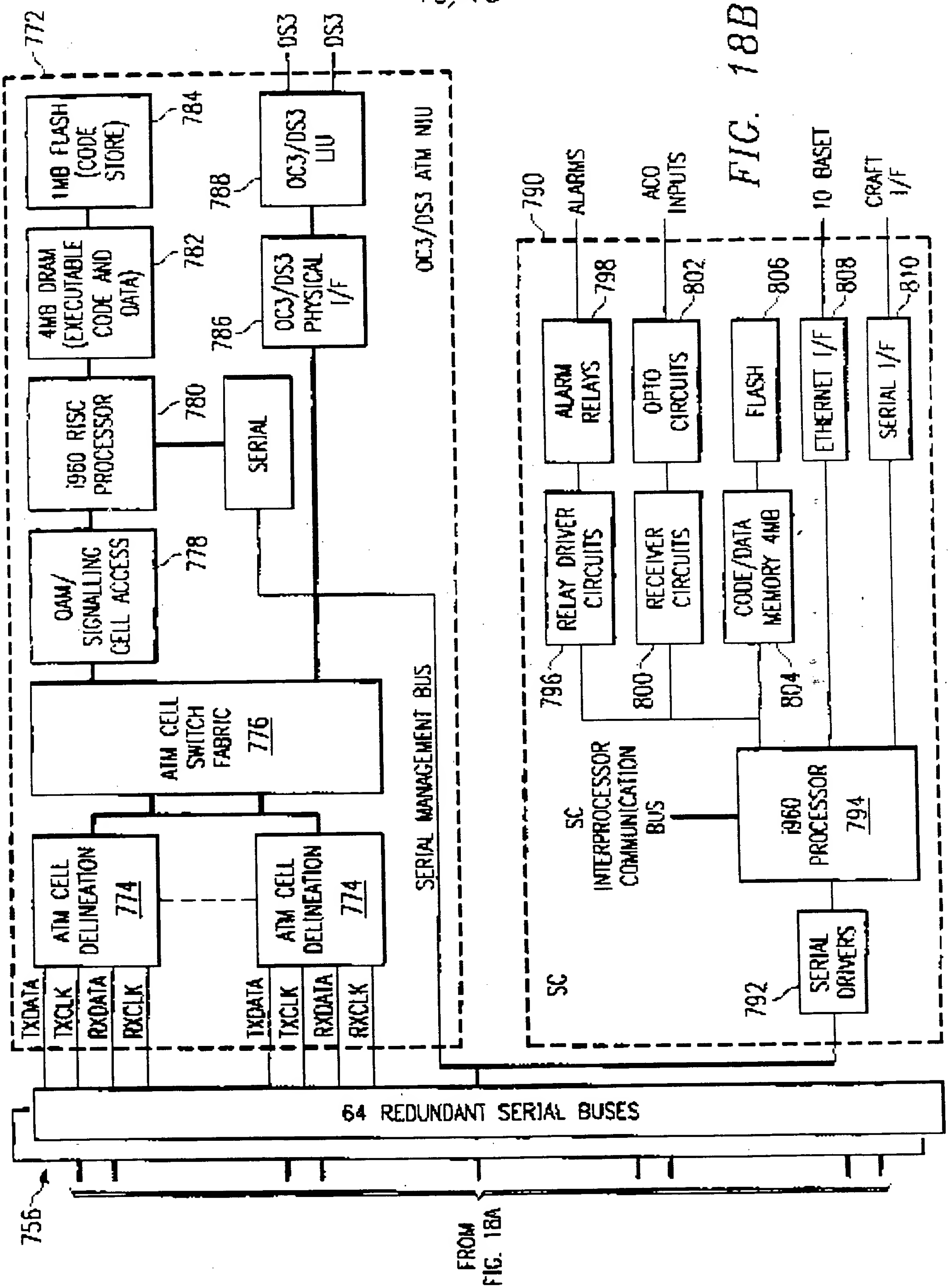

772
1MB FLASH (CODE STORE)
784
4MB DRAM (EXECUTABLE CODE AND DATA)
782
i960 RISC PROCESSOR
780
SERIAL
OAM/ SIGNALLING CELL ACCESS
778
ATM CELL SWITCH FABRIC 776
ATM CELL DELINEATION 774
ATM CELL DELINEATION 774
TXDATA
TXCLK
RXDATA
RXCLK
DS3
DS3
OC3/DS3 LIU
788
OC3/DS3 PHYSICAL I/F
786
OC3/DS3 ATM NIU
SERIAL MANAGEMENT BUS
790
ALARMS
ACO INPUTS
10 BASET
CRAFT I/F
ALARM RELAYS
798
OPTO CIRCUITS
802
FLASH
806
ETHERNET I/F
808
SERIAL I/F
810
RELAY DRIVER CIRCUITS
796
RECEIVER CIRCUITS
800
CODE/DATA MEMORY 4MB
804
SC INTERPROCESSOR COMMUNICATION BUS
i960 PROCESSOR 794
SERIAL DRIVERS
792
SC
64 REDUNDANT SERIAL BUSES
756
FROM FIG. 18A

FIG. 18B